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HSE Risk Monetization and Well Construction Fluids: Presenting a Method for Comparing the Costs Associated with Fluid-related HSE Risk and its Consequences

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Abstract

A key decision in well construction planning is the choice of which well construction fluid (WCF) to use. The properties of the chosen fluid affect overall operation economics both directly, i.e. through operational costs such as waste handling and indirectly, i.e. through costs related to, for example, environmental consent requirements. Choosing the most appropriate and cost effective WCF is a significant part of successful well planning and requires a sufficiently broad overview to capture all the cost points.

This paper presents a method and a supporting tool for taking into account direct costs, operational costs and HSE related costs when comparing WCF options. The development of a systematic, reproducible yet operation-specific approach to assess the overall cost attributable to choice between alternative WCF options is described.

In order to support overall efficiency, the variables considered have to be comparable. To be able to compare like for like, different operational costs, health, safety and environment (HSE) consequences and risk potential need to be translated into the same language as the outright costs of the fluids, i.e. into money. However, both quantification and absolute costing of HSE risks are laborious undertakings. In addition, the available methods for absolute calculations are not universally accepted. For this reason the monetization of HSE risk and the linkage of the associated operational consequences to tendered fluid choices have rarely been attempted in the past. Another obstacle has been the lack of a simple tool for making comparisons, and the absence of an agreed systematic and objective framework for the assessment.

This paper describes the development and workings of a novel tool for monetizing the HSE risks posed by different WCF. The tool is simple to use yet allows objective comparisons, using familiar Excel spreadsheets. It provides the full framework for comparing the fluid option, using real data input provided by the operating company requiring the comparative output. Importantly, the tool allows the users to reflect their individual company HSE values in the costing projections through application of weighting factors. At the same time, the assessment process provides the users with a clear overview of the comparative HSE risk levels and the associated financial implications of choosing one or the other of the assessed fluids. The power of the tool as a decision supporting framework for well planning is demonstrated through assessment of the comparative cost structure of two high-density brine systems commonly used for well control.

Introduction

Well construction operations at offshore deepwater sites or other demanding environments can easily come with a price tag of tens of millions of dollars. The costs of using a WCF in such operations are significant items in the final bills and can vary considerably according to the fluids selected. The choice of WCF has both immediate tangible costs (price of fluid) and consequential costs through the effects on operations, HSE and waste creation. An example of the HSE cost related points are pictured on Figure 1 below. Comparing fluid alternatives for only direct costs (e.g. the cost/bbl, as stated on the fluid tender) does not capture the numerous consequential costs.

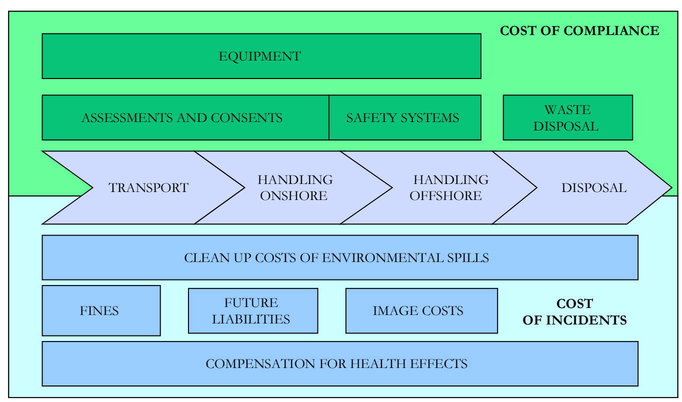

Figure 1: Different HSE cost points related to fluid use

It is well-known that the choice of WCF has a bearing on other aspects of the well construction program. It is however quite challenging to identify, define and quantify all these effects and their costs in a comparable manner, although several models exist for what to consider, such as the checklist by the US EPA[1] and briefly described in this paper. In order to be able to do this, the first hurdle is to collate the data from various sources and present it in a coherent format. In order to avoid drowning in a sea of detail some simplification of the overall issues considered is required. This paper presents the considerations and objectives for developing a systematic yet easy to use cost model for quantifying and comparing the overall operational costs, HSE consequences and risk associated with the use of WCF.

The target has been to facilitate the assessment of fluid choice comparatively, transparently and from a broad operational economic point of view. In order to do this, a model has been created. The model demonstrates the differences in cost that can be attributed to the HSE properties of a fluid. Two high-density completion brines with widely differing HSE properties have been used as examples throughout the development work: cesium formate and zinc bromide. In order to enable operators to carry out the assessment rapidly and at an early stage in the well planning cycle, a supporting tool in Excel is presented.

Aim and objective, methodology and structure of the paper

This paper presents a methodology that allows informed cost assessments to be made regarding which WCF to use in a particular operation.

The overall aim of the work has been to develop a methodology that allows cost comparison of fluid alternatives with different pricing structures, different operating costs and different HSE properties. The objective is to enable management to consider both overall operational aspects and comparative HSE risk of fluid alternatives in a systematic and repeatable manner. The following targets were set for the work:

- Develop a framework for comparing the overall operational costs associated with WCF choices that allows the comparison of chemicals with different pricing models
- Develop a method of defining comparative chemical risk in terms of cost that allows both tangible and intangible costs to be taken into account
- Scope the criteria for monetization of chemical risk through reflecting the cost of legal requirements, liability trends and covering the entire chain of operations
- Find a way to measure uncertain costs
- Implement an Excel based operational tool that can be tailored to each operator's policies, risk aversion, previous history and locational cost structures.

Each fluid is in principle stored, transported, handled and used in a similar manner – albeit the details may vary according to from where, by whom and on the fluid properties. Nevertheless, the risk of something happening can be considered from a chain-of-events point of view. In addition to risk, the stages of the overall operations also have some immediate operational consequences. These have been included in the consideration in order to arrive at a cost of actually using, storing, transporting and disposing the fluid choices. These costs are directly associated with the fluid properties

The different operations that have been identified in this case are pictured in Figure 2.

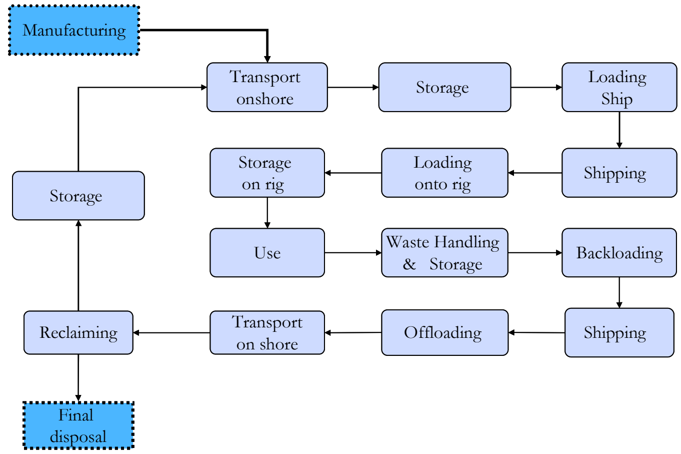

Figure 2: The chain of events involving WCF considered in the study

The method and tool development work has been based on an interactive study, utilising an extended round of interviews and meetings with potential users and incorporating a presentation of the prototype for comments to operators. Input has been sought from operators, field engineers, well designers and fluid manufacturers. The team working on the model has included expertise in risk management, economic modelling, ecotoxicology, HSE and statistics.

The paper progresses from the general to the specific. To set the scene, the drivers and objectives for the methodology development are briefly described. Secondly, an overview of the theoretical considerations taken into account is presented. The main part of the paper discusses the practical aspects of the methodology and the simple assessment tool developed to allow such comparisons. Finally, results obtained using the tool are discussed.

Drivers for the development

The overall technical performance of any WCF is continuously balanced against the cost of the fluid. In principal, the decision making question applied to the choice of WCF can be boiled down to the consideration of how much relative operational advantage is achieved through using a certain fluid at a certain cost. There is, however, no simple equation that accurately predicts this future outcome.

A main driver for reducing chemical HSE risk is the legislative and more general societal pressure for improved HSE performance. Tightening regulatory demands[23] also lead to higher direct costs, which can be related to the chemicals inherent HSE properties as follows:

1. The operator has to ensure that any chemical use is legal, i.e. meets consent conditions. More hazardous chemicals are likely to require more stringent consent conditions, such as extensive personal protective equipment, waste treatment or monitoring practices.
2. The cost of mitigation and potential liability can be related to the degree of hazard as represented by the

substance's HSE properties. Legislation also frequently emphasises preventive actions and the pressure towards substituting (or eliminating) chemical use with less hazardous options is evident[4].

Selecting the most cost-effective WCF is complicated by the fact that the cost consequences of fluid choice are spread across a number of functional department in the oil company using the fluid. The choice of fluid has consequences for operational cost in several dimensions (time, waste, risk…) and these items may appear in different budgets or be measured differently (volumes versus values, compliance versus cash). Hence consequences from a particular WCF choice may be felt remotely (usually downstream) in "someone else's budget" and therefore not noted as an input to the decision making. Indeed, linking the consequences to the initiating source of the consequences may be easy in theory, but may be very complex in practice. Nevertheless, optimization of operations and maximization of company profits require an overall view of the cost structure of WCF choices. The consideration of HSE as a cost factor in overall management decisions is therefore amply justifiable.

This necessitates a systematic inclusion of overall operational costs and HSE risks as integral parameters in the overall decision making analysis processes. The lack of such a systematic, yet easy to use, framework to support this was identified as a key issue to tackle. *To enable well construction teams to look beyond the sums on the fluid tender and base decisions on final costs to their employer and shareholders, a fast, comparative assessment of the overall costs stemming from fluid choices is required.*

In order to have practical application, the model has to be simple to use yet robust enough to tackle a complex problem as part of daily decision making. Hence the model is supported by a simple spreadsheet tool. The framework itself is tailored by each user. The approach allows the setting of values on intangible aspects such as health. To be widely applicable, the model has been set up to allow it to be tailored to each operator's own data and experience, including:

- corporate policies,
- incidence frequencies
- locational requirements and
- risk acceptance willingness.

Choosing WCFs for comparison

In order to highlight the cost differences attributable to differing fluid HSE hazard properties, two well completion fluids with widely differing HSE profiles and large differences in initial prices for the fluid have been used as examples. Cesium formate is used as an example of a WCF with a comparatively positive HSE profile. The overall cost structure of cesium formate is then compared to a traditional zinc bromide brine with a less flattering HSE profile[5] but a considerably lower purchase price tag in terms of $/bbl fluid.

The chemicals compared are briefly described below. Additional information on their HSE properties is presented in Table 1 (see end of paper)

Cesium formate (CsCOOH) is highly soluble monovalent salt which forms high density, alkaline brines. It dissociates into cesium and formate ions and the formate part is readily biodegradable in seawater and fresh water medium. Cesium formate is **slightly or practically non-toxic** to marine organisms (e.g. acute LC_{50} values generally > 300 mg/l). To freshwater organisms it is moderately toxic, but the toxic effect is thought to be related to nutrient depletion caused by formate rather than to direct toxic effect[6]. For human health the brine is relatively easy to handle on an oil field site, although it is harmful if swallowed and it may irritate eyes. [7,8]

Zinc bromide ($ZnBr_2$) is an inorganic salt that forms high density acidic brines. It exists in aqueous solutions as dissociated into zinc and bromide ions. Corrosive zinc bromide is **moderately to highly toxic** to the aquatic environment (it is classified as a priority pollutant)[9]. Like other divalent halide brines it is hazardous to human health, capable of causing severe skin burns that require casualty hospitalization and even plastic surgery. [10, 11]

Some theoretical considerations

Assumptions and simplifications

Absolute calculations are time consuming and difficult. Comparisons of operational consequences between two options give more freedom to simplify the methods as long as the simplification is applied in equal measure to both options.

The cost model presented in this paper has been developed based on some fundamental assumptions and simplifications. These are:

1. Not all operations have to be considered in all comparisons. As long as the comparison is done for the same operations for both fluid options, the results are valid for those operations.
2. Risk scenarios for the logistic chain vary mostly in their root causes (what led to the incident). The outcomes can be much simplified and related to spills (environment) and splashes (humans) and the direct costs of these consequences. The incidents can occur anywhere in the chain of events. Hence specific risk scenarios represent a hypothetical picture of a specific incident, which is representative of the potential outcome of thousands of similar accidents. The risk scenarios aim at capturing the hotspots in the fluid handling chain (see Figure 2). However, they are equally applicable to many other incidents, too. This is depicted in Figure 3.

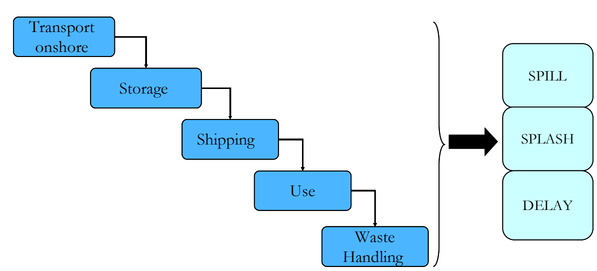

Figure 3: The universal applicability of the risk scenarios associated with fluid handling

3. The use of WCFs carries a certain degree of chemical HSE risk, in proportion to fluid properties. Therefore some HSE risk is present wherever the fluids are handled, used, stored or transported. The inherent hazard of the fluid influences the consequences of incidents. In other words, the nature of the fluid will determine whether an incident is simply a small mishap, a minor accident or a major large scale accident. To illustrate, spilling top-hole section drilling fluids such as seawater and sweeps is annoying and may cost some time but is unlikely to damage the marine environment or humans. On the other hand, splashing of even small amounts of corrosive fluids may cause severe damage to the persons handling the fluids. This is illustrated in Figure 4.

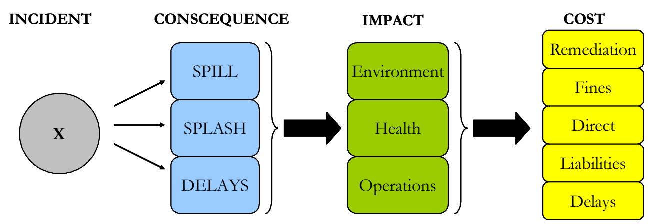

Figure 4: Fluid accidents - From incident to consequences

4. The risk scenarios cover land and marine transport as well as use. Any one particular scenario can be left out of the consideration. However, taken all together, they represent a truer picture of the overall incident potential in the chain.
5. Statistics on specific incidents is scarce or not available, not comparable or the collection principles are not transparent. Hence the incident frequencies that best depict what could happen in the operation should be decided by the operator. This way there is no skewing towards industry averages without consequences for the operator.
6. Consequences to humans and environment can reliably and without a full scale ethical discussion be measured in money **only** through estimating in advance or measuring post-event direct incurred costs. These are the items such as hospitalisation costs, surgery costs, environmental restoration, excavation work and other similar costs. However, the intangibles cannot be ignored (e.g. natural beauty, human life, pain etc.). (See also Figure 1) The model is based on allowing the operator to take the intangible factors of an incident into account without extensive calculations through using weighting of direct costs.

There are many potential ways of calculating fluid cost, operational differences and HSE risk. The relative differences can be based on many other assumptions than the above and include many different variables. None of the alternatives are necessarily the ultimate and only right solution for all situations. However, the model allows the users to base their decisions on the best data and best guesstimate they have without getting bogged down in the minutiae and precise differences.

Investment consideration is generally based on an inclusion of overall costs and risks of each option and relating these to the benefits. For example, whilst the initial cost for a sixth generation rig may be several times more than the expenditure for an older rig, the benefits of paying more can be related to faster drilling speed and the ability to perform in deeper water. Maximising benefits whilst minimising expenditure is the simple formula for success.

By considering the overall operational cost, WCFs with differences in, for example initial pricing or charge models, can be compared on a more equal level.

For other costs, the relationship between direct costs, benefits and risks may be even more complex to see. This is particularly true when it comes to the intangible areas of health, safety and environment, where costs are related to both consent and incidents. Significant costs may only occur if something goes wrong and may therefore be overlooked as part of the operation economics. Particularly from an investor's point of view, including the cost of HSE risk as well as the overall operational costs allows better choices.

Whilst the model is neither scientifically revolutionary or the only potential route to take, it nevertheless provides a practical framework for systematisation of comparative assessments. Through allowing tailoring of the risk factors and probabilities to the operators own experience and policy, the method combines practicality with good management practices and allows the team to work to its own risk aversion

The assumptions related to risk

A particularly important consideration is to ensure that uncertainties in incident frequencies do not unduly influence the results. One of the key challenges was to create a mechanism, whereby the cost of different risk scenarios can be calculated without drowning in a sea of details and uncertainties. In order to take the discussion from a theoretic view to the practical, some simplifying assumptions therefore have to be made. These are summarised below:

1. Overall risk is the sum of the risk for separate incidents
2. Incident risk is the product of consequences of an incident and the probabilities with which it may occur
3. Accident probabilities can vary between operators
4. Consequences of incidents involving a certain fluid are related to the fluid HSE hazard properties

Incidents can therefore lead to minor or major accidents, depending on the course of events. Although it is clearly true that major incidents occur less frequently than minor incidents, a method of summing the risk over the chain of operations that involves the fluid is required.

In order to accommodate the calculation of HSE risk costs in a consistent way that accommodates the operators' values and track record, the following decisions were made:

1. The cost of a particular incident is calculated for both a typical and a worst case scenario.
2. The operator sets the frequency of incidents to reflect their experience and predictions
3. The overall frequency of incidents is, on average, the same regardless of place in logistic chain
4. The cost of risk is the average of the sum of all the cost of all incurred incidents

The frequency of the events, i.e. establishing how likely an event is to occur, is perhaps the most difficult question. The scarcity of available reliable, accurate and comparable incident information has been counteracted by approximating the risks through **scenario analysis.** The costs of realisation of risk are calculated for four typical and four extreme case scenarios. The scenarios have been developed to represent the entire chain of operations, from transport to use on the rig, as depicted in Figure 2.

Total Cost Structure Model

Whilst the simplest of all cost calculations inevitably is a straight comparison of the cost of a barrel of fluid , it is argued that better decisions can be made when both running costs and the cost of risks are included in the consideration. The cost of HSE risk is here calculated based on incident frequencies (as set by operator), cost of direct consequences (HSE and operational) and potential legal costs. The scenario costs are then summed and averaged to give the predicted cost of HSE risk per well. This is depicted in Figure 5 in a simplified manner.

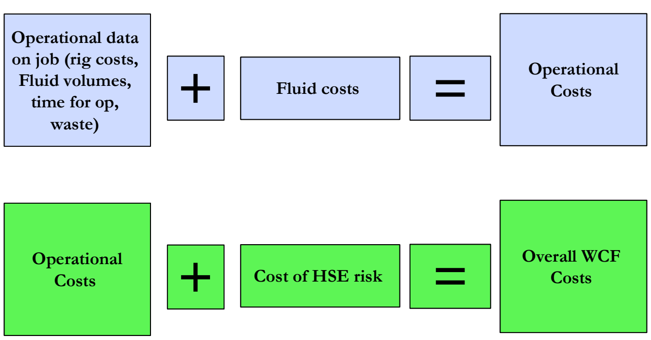

Figure 5: The overall calculations

The actual cost structure considered in the model can be divided into three parts of calculations:

1. Direct costs for the fluids
2. Direct operational consequences related to the fluid choice, such as environmental consent conditions specifying how to treat waste
3. The Direct cost of HSE risk realization and taking into account intangible HSE values through weighting.

In this paper, the question of absolute gain is not considered *per se*, instead the focus is on determining a simple way of arriving at comparative cost structures for these three aspects. This is described in the following three subchapters.

Fluid costs

The direct costs include taking into account fluid sales terms and predicted fluid losses. These are specified by the operator and fluids company.

Operating costs

The direct operational consequences are arrived at from a consideration of the operations and the different variables dependent on the fluid HSE properties. These include:

- Onshore transport
- Shipping
- Personal protection
- Suboptimal rig time
- Completion operations, waste transport
- Delay in production
- Fluid related other operational costs
- Produced water ship-to-shore
- Produced water treatment on rig
- Waste disposal
- Handover costs to production

The model is based on ensuring that each of the variables can be specified separately to fit the specific operational environment.

Costs related to HSE risks

There is no simple or all inclusive formula for calculating absolute HSE risk, and certainly none for putting a price tag on the risk factors. In order to arrive at an informed decision within the constraints of practicality, managers need a consistent, transparent and comparative method/model. This should allow the operator to assess the difference in operational costs and the difference in risk as well as the difference in price for fluid.

Some official guidelines on monetization of HSE risks exist. A highly relevant one for this case is guidance issued by the U.S. Environment Protection Agency[12]. The EPA lists issues which should be taken into account when considering overall cost of using a particular technique or chemical. These include:

1. Compliance obligations related to laws and regulations that apply to **the manufacture, use, disposal, and release** of chemical substances and to other activities that adversely affect the environment.
2. **Remediation** obligations (existing and future) related to contaminated real property
3. Obligations to pay **civil and criminal fines and penalties** for statutory or regulatory non-compliance
4. Obligations to **compensate private parties** for personal injury, property damage, and economic loss
5. Obligations to pay "**punitive damages**" for grossly negligent conduct and
6. Obligations to pay for **natural resource damages**.

These guidelines have been used as a baseline for the monetization approach adopted in the tool. To do this consistently, a common set of variable to consider is required. These variables are simply the collection of issues that need to be taken into account presented in a systematic an easily repeatable manner. Whilst the theoretic discussion is fraught with uncertainties, the objective of this work is wholly practical: to distil a fast, reliable way of comparing costs for fluids with different HSE properties. Therefore only HSE costs occurring as direct consequences are used. The input variables are grouped in the tool as follows:

1. Health and safety related costs
  - Medical treatment and or hospitalisation and associated transport
  - Loss of worker productivity

2. Environmental costs
  - Excavation costs
  - Recovery costs
  - Remediation costs

3. Direct legal costs
  - Fines
  - Compensation to society and individuals

As it is nigh impossible to find comparative data on occurred incident costs with the substances in question, the costing of legal consequences has been based on a qualitative assessment of the HSE consequence scenarios of incidents combined with court cases and data relating to monetary consequences. The data included is based on the following types of data publicly available:

1. Known costs for the substance in circumstances as specified in the scenario
2. Known costs for another, but similar substance, in circumstances as specified in the scenario
3. Costs predicted by operations required to remediate the incident, based on toxicology and other effect related data[13]

However, the data used are not absolute, and the cost points can easily be amended to reflect any additional data or knowledge.

Linking method with practice – the tool

The model aims to enable well construction project or asset managers to include the HSE related overall costs of fluid in all decision making *on par* with other costings. The format chosen for this is a simple Excel based tool that supports systematic assessment of fluid alternatives. This enables the operator to take into account not only the cost per barrel of fluid, but also the operational consequences of choosing a particular fluid.

The following aspects were identified as key targets for the tool:

- User friendliness
- Scientific integrity
- Repeatability
- Simplicity and
- Flexibility

The tool design process included several stages of feedback from users and experts. The overall process included literature searches, prototype building of both the model and the supporting tool, fine tuning the parameters, variables and calculations used through user feedback.

Throughout the work, cesium formate was used as the reference chemical. Cesium formate is particularly well suited for the comparison, as the fluid has a relatively high cost per unit, a very good track record of performance and an excellent HSE profile.

The tool itself is structured in three different parts. This allows different departments and disciplines to combine their input into one systematic assessment. The structure is depicted in Figure 6.

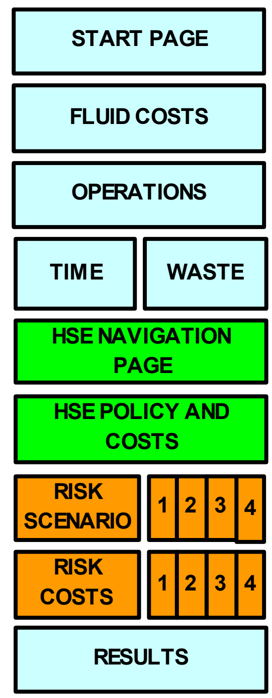

Figure 6: The overall structure of the tool

The first step is to determine the fluid costs, based on the sales terms, predicted usage and losses, as seen in Figure 7 below.

FLUID COST DATA

FLUID REQUIREMENTS AND OPTIONS CONSIDERED		
Brine density required	15,40	PPG
Brine volume required	1 000	bbl
Fluid option 1	Cesium Formate	insert name
Fluid option 2	Zinc Bromide	insert name

FLUID COSTS	Cesium Formate	Zinc Bromide	Unit
Sales terms	Rental	Sale&return	
Fluid cost	1 268	622	US$/bbl
Daily rental	11	NA	US$/bbl
Fluid rental / usage time	60	NA	days
Buyback terms on returned fluids	NA	80 %	
Predicted fluid losses (surface and down hole)	10 %	10 %	of total brine volume
Fluid losses during reclamation	2 %	5 %	of total brine volume
Losses due to dilution of brine system	1 %	1 %	of total brine volume
Total fluid losses	130	160	bbl
Percentage of fluids returned	87 %	84 %	
Cost of using fluid	604 197	104 563	US$
Cost of lost fluids	164 783	99 584	US$
Fluid cost for the operation	**768 980**	**204 147**	US$

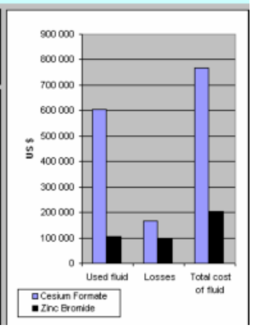

Figure 7: Screenshot from tool – Fluid costs

Secondly, the operational costs are considered (See Figure 8). The points taken into account are:

- General economic parameters and production estimates
- All inclusive daily rig cost
- Cost of separators for produced water
- Standby cost of ship (for waste water)
- Fluid option related time losses
- Other operational costs
- Waste volumes and waste disposal costs
- Cost at handover to production operations

OPERATIONAL DATA

BASIC ECONOMIC PARAMTERS AND PRODUCTION ESTIMATES			
Price per oil equivalent		90	US$/bbl
Yearly interest rate		6 %	
Expected initial production (oil equivalent)		10 000	bbl/day
Expected produced water volume		200	bbl/day
OPERATIONAL COSTS			
All inclusive daily rig cost		960 000	US$/day
Cost of separators for produced water		6 000	US$/day
Standby cost of ship (for waste water)		40 000	US$/day
FLUID OPTION RELATED TIME LOSSES	**Cesium Formate**	**Zinc Bromide**	
Suboptimal rig time (from separate sheet)	0,00	1,00	days
FLUID RELATED OTHER OPERATIONAL COSTS	**Cesium Formate**	**Zinc Bromide**	
Material compatibility cost			US$
Other, please specify			US$
FLUID OPTION RELATED WASTE VOLUMES	**Cesium Formate**	**Zinc Bromide**	
Waste fluid volumes generated (from separate sheet)	0	280	bbl
Produced water treatment	NA	Shipped to shore	
Days until produced water can be discharged	0	2	days
Contaminated produced water requiring shipping	0	560	bbl
COSTS AT HANDOVER TO PRODUCTION OPERATIONS	**Cesium Formate**	**Zinc Bromide**	
Fluid return comingling with production stream			days
Separation cost from hydrocarbon stream			US$/day
Waste fluid volume generated from initial production (slops in barge)			bbl
Hydrocarbon mingled waste fluid treatment cost			US$/bbl
Other, please specify			US$

Figure 8: Screenshot from tool – Operational costs

The HSE related costs are specified in accordance with Figure 9 below and include:

- Defining corporate values
- Setting the HSE Consequences to match operator experience
- Translating HSE risk into Costs

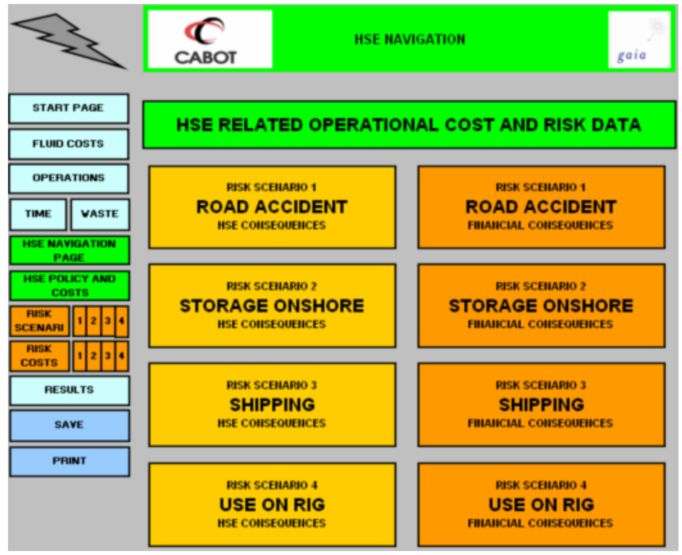

Figure 9: Screenshot from tool – HSE data navigation page

The HSE consequences are assessed for humans and the receiving environment. The consequences are related to hazardous properties, as drawn from toxicological test results. In order to take into account the full societal cost, the legal consequences as well as restoration costs have been considered.

Legal requirements form the basis for certain costs, especially costs related to environmental properties (e.g. whether the chemical can be discharged or has to be contained). The fact that any mitigative action can be costly, time consuming and image damaging can also be recognised as a driver for stringent corporate HSE policies.

Risk management includes hazard identification, assessment and control of incidents (occurrence is minimised) as well as minimisation of consequences after an incident. For alternative WCFs used, stored and handled in same amounts, the frequency of an incident occurring is largely similar. However, for each WCF alternative, the consequences of an HSE incident are related to the chemical properties (chemical hazard). The cost of HSE risk is calculated based on direct costs, as previously explained.

The overall flowchart of how the developed cost calculations are linked is shown in Figure 10.

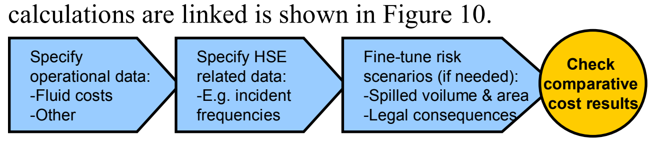

Figure 10: Flowchart of the tool usage

Output from the tool

The tool calculates the following results:

- Total fluid costs and losses
- Total operational costs
- Average cost of incident consequences

It also compares the following cost summaries:

- As planned (XX % of wells, percentage set by the

operator as representative of the number of wells in which no HSE incidents occur)
- Operations outside planned (small to average HSE consequences, XX % of wells)
- Operations outside planned (larger than average HSE consequences, XX % of wells)

The tool then calculates the average cost per well. The risk of having to spend additional sums is also presented with the confidence levels (xx below) as specified by the operator:

- Additional cost, which is attributable to a small incidence risk to occur during WC (with xx % confidence)
- Additional cost, which is attributable to a medium to major incidence risk to occur during WC (xx % confidence)

The summary is given as a graph, as presented in Figure 11.

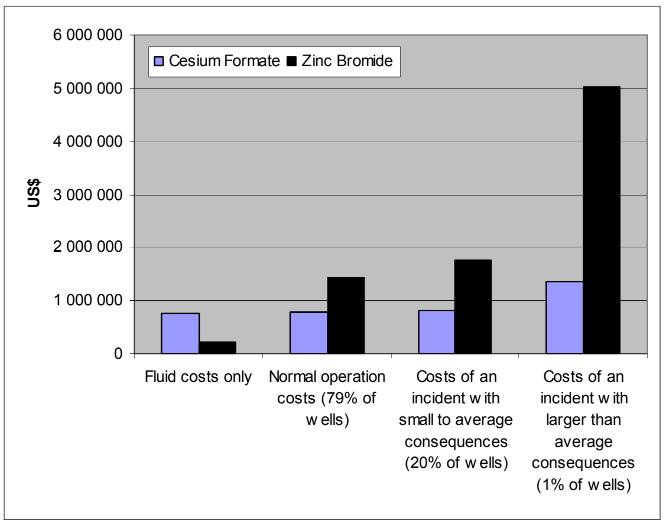

Figure 11: Cost summary

The structure of the tool has been tailored to facilitate the use of the tool by different sets of experts. Hence the direct, operation related data is separate from the HSE related inputs. The actual tool is based on the familiar Excel spreadsheets and does not require the installation of any new software. The construction of inputs allows the tool to be used for any well construction fluids, as the key inputs are substance specific. However, the actual risk assessment included has been specifically carried out for the two case fluids. Running the tool for any other fluids would require modification of the verbal risk assessment part as well as manual checking of the potential legal consequences of incidents. However, a general sensitivity analysis can be carried out through the changing of key inputs.

Discussion

The main benefit of the developed approach is the enabling of a simple, fast and comparative examination of the overall cost associated with the choice of a particular WCF. By including cost points arising from the overall operations, a wider relationship between fluid choice and cost can be established. This allows management to make decisions based on overall well economics and take into account HSE in the same way as other cost points. The method is easy, transparent and because it is based on a comparison rather than absolute truth, circumnavigates the complexity of attempts to arrive at definite sums. The use of the tool facilitates the creation of an overall view of the different budgetary consequences of the choice of WCF. Easy and fast to use, update and share, the tool can also be used to run sensitivity analysis, although this is not currently automated. Despite the clear benefits to be had, there are nevertheless always drawbacks related to simplification. For example, the differences between the cost structure is perhaps particularly clear between fluids with such widely different HSE properties as cesium formate and zinc bromide. The HSE risk assessment is also simplified, and does not meet the requirements of a rigorous ecotoxicological and /or occupational health and safety assessment, which still would need to be done in detail in some cases. However, as a comparative decision making tool, such simplification is considered defensible and even desirable.

The decision to keep the incident rate as a flexible input allows each operator to tie the results to an incident rate that has a foundation in reality to them. The setting up of the HSE risk part to reflect locational and company specific cost structures requires input from the operators HSE department. The operational costs related to HSE properties on the other hand require first hand knowledge of the operational procedures. The best results are achieved if values from previous similar operations are used. However, through basing the assessment on existing datasets such as previous court cases, the operator ensures chemicals are assessed in a comparable way.

Conclusions

Fluid related technical performance and risk of underperformance is routinely assessed as part of the well design program. Risk to workers and environment are assessed as part of consent applications or internal audits. The management of the logistical chain to ensure on time delivery is closely monitored. Rig time is at a premium and its costs closely monitored. However, in order to assess the overall consequences and costs of the alternative WCFs, input from all the relevant budgets and assessments have to be brought to the same table for consideration.

Efficient chemical risk reduction benefits from tools that allow HSE risk translation into cost. Whilst there are many theoretical issues associated with the costing of intangible aspects such as health or natural beauty, these are considered to be outweighed when the approach is a comparative rather than absolute.

The developed methodology and associated tool is based on sound risk assessment practices and financial methods. Overall, the tool and the methodology support integration of consideration of chemical HSE hazards and risks in the overall decision making process.

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References

[1] US EPA. "Valuing Potential Environmental Liabilities for Managerial Decision-Making: A Review of Available Techniques." EPA 742-R-96-003, 1996.
[2] Gilbert, Y., Pessala, P., Vaahtera, A. and Raivio, T. "Formate Fluids and Environmental Regulations: A global view of benefits and challenges", SPE 110891, 2007.
[3] Gilbert, Y., Nordone, A., Downs, J., Vaahtera, A., Pessala, P. and Raivio, T. "REACH and the HSE Case for Formate Brines". IPTC 11222, 2007.
[4] Gilbert, Y., Raahauge, P. and Raivio, T. "Managing Chemical Risk at the Point of Procurement – Simple Tools for Efficient Chemical Risk Reduction." SPE 111673, 2008, in press.
[5] Gilbert, Y. and Pessala, P. "Cesium Formate and Zinc Bromide – Comparative Hazard Assessment and HSE Profiles." Gaia Consulting Ltd, 2007.
[6] NICNAS *Full Public Report – Cesium Formate – File No NA/811*, National Industrial Chemicals Notification and Assessment Scheme, Sydney, 2001.
[7] Cabot. "Material Safety Data Sheet. Cesium Formate Solution. " 10.4.2007.
[8] Gilbert, Y. and Pessala, P. "Cesium Formate and Zinc Bromide – Comparative Hazard Assessment and HSE Profiles." Gaia Consulting Ltd, 2007.
[9] U.S. 40 Code of Federal Regulations, Appendix A to Part 423—126 Priority Pollutants.
[10] WHO. "Environmental Health Criteria 221, Zinc." Geneva, pp 254, 2001.
[11] Gilbert, Y. and Pessala, P. "Cesium Formate and Zinc Bromide – Comparative Hazard Assessment and HSE Profiles." Gaia Consulting Ltd, 2007.
[12] US EPA. "Valuing Potential Environmental Liabilities for Managerial Decision-Making: A Review of Available Techniques." EPA 742-R-96-003, 1996.
[13] Gilbert, Y. and Pessala, P. "Cesium Formate and Zinc Bromide – Comparative Hazard Assessment and HSE Profiles." Gaia Consulting Ltd, 2007.

Tables

Table 1. HSE properties of cesium formate and zinc bromide brines.

	Cesium formate	Zinc bromide
Health		
Ingestion	Harmful if swallowed.	Severe burns to mucous membranes of mouth, stomach and oesophagus.
Inhalation	No significant inhalation hazard to be expected.	Corrosive to mucous membranes and upper respiratory tract.
Skin & eye	Irritating to eyes and skin.	Corrosive, may cause severe irritation or burns on skin and eye damage.
Chronic	No significant chronic hazard to be expected.	Repeated skin contact may cause dermatitis. Repeated intake may affect the central nervous system.
Safety		
Labeling	Harmful	Corrosive, dangerous to the environment
Transport	Not classified as dangerous goods for the purposes of transport by rail, road or in packed form by sea. Has no UN number nor requires any specific labelling for transport requirements. Subject to the IBC code (Ship class 3 and pollution category Z).	Dangerous goods class, proper shipping name, UN Number and note "marine pollutant" on the documentation are required. Labelling with "Class 8 - corrosive substances" and "marine pollutant" label required. Subject to the IBC code (Ship class 2 and pollution category X).
Environment		
Acute	Slightly or practically non-toxic to marine organisms, moderately toxic to fresh water organisms	Moderately to highly toxic to aquatic environment
Chronic	Long-term adverse effects in marine environment not to be expected.	Potential to cause long-term adverse effects in the aquatic environment. Sublethal effects such as interference with reproduction and developmental processes possible.