4.0 ECONOMIC ANALYSIS

4.1 COSTS ESTIMATES

4.1.1 Cost Categories

A risk assessment has been conducted for the SPL site (Hatfield 2009a); three different scenarios have been proposed to reduce the risk associated with POPs contamination at this site. Mitigation measures that need to be implemented (in terms of infrastructure and equipment needs, labor, maintenance requirements, etc.) cannot be determined accurately unless substantial design work is undertaken (this is especially true for scenarios involving engineering work, the scope of which has to be clearly defined on a site-specific basis).

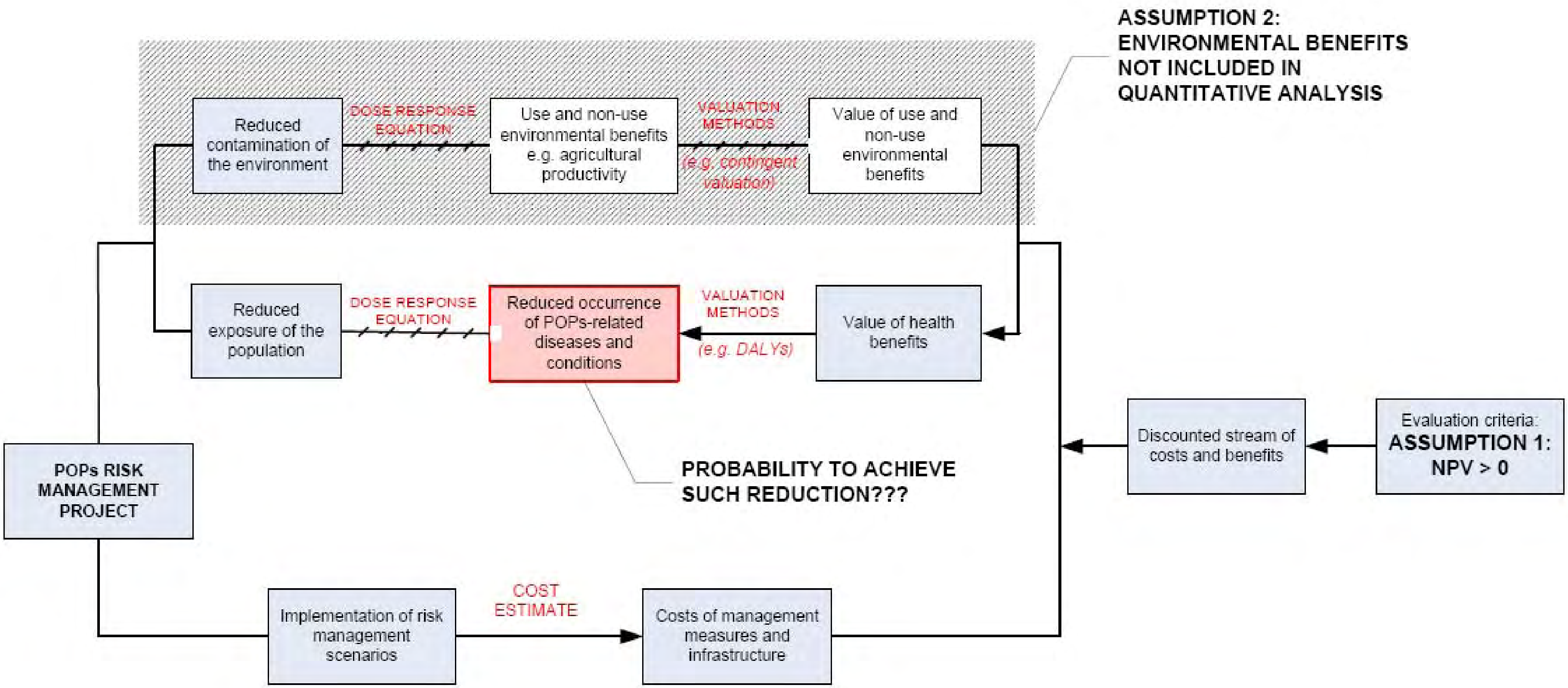
Cost categories were developed for each scenario, based on site characterization data obtained during the risk assessment and from consultation with project stakeholders. Where no data were available, professional judgment was used to make assumptions.

The cost categories and the associated quantities for each scenario proposed at the four hotspots are presented in Appendix A2.

4.1.2 Cost Data Sources

The limited time and resources available for conducting the economic analysis did not allow for the collection of primary data. Furthermore, locating data from secondary sources that would be applicable to the project was a major challenge for the following reasons:

Figure 3 Modified approach to the Cost Benefit Analysis, as applied to the POPs Project.



- Cost databases (e.g., catalogues) are regularly compiled in developed countries by professional bodies or institutions (e.g., the Historical Cost Analysis System [HCAS] developed by the US Army Corps of Engineer collects and store historical cost data for Hazardous, Toxic, and Radioactive Waste remedial action projects), but they are not commonly available in developing countries where markets tend to be less structured;

- Without a detailed scope definition for the proposed scenarios (and specifically for the engineering work they require), cost estimates that could be found for similar projects are of limited use; the physical parameters enabling these costs to be scaled up or down to adjust to site-specific conditions need to first be determined; and

- Unit costs are often characterized by their large variability, since they may not apply to the exact same type of goods or services. For example, in the "*Inventory of Worldwide PCB Destruction Capacity*" (UNEP, 2004), the cost for PCB oil treatment ranges from US$30 to $3,700 per ton. Even with a narrow focus (PCB destruction) and significant resources for data gathering (a detailed questionnaire was filled out by 42 treatment companies), the study could not provide a "standard" unit cost with accuracy, but only a rough order of magnitude.

For these reasons, the cost estimates developed as part of this economic analysis are preliminary and of limited accuracy. However, this should not be seen as critical in the specific context of the present project. It is recognized that the cost benefit analysis is primarily aimed at determining what level of investment is economically viable rather than assessing the actual "performances" of each scenario. In addition, the general framework of analysis can be reused through various iterations, and the results progressively refined, as more data become available.

A unit cost list for each country, presenting the various cost data used and their sources is included in Appendix A2.

4.1.3 Results

The cost estimates for the various scenarios are based on the assumptions described in Appendix A2. Key assumptions are presented below.

- <u>Scenario 1</u>: Health & Safety / Spill Prevention Plan: Scenario 1 focuses on safety improvements and spill prevention through the education of workers who come in contact with POPs. It involves no "hard" engineering. The first year of its implementation is associated with the development of a Health and Safety/Spill Prevention Plan and associated training; the purchase of material (personal protective equipment); and the modification of the workplace. Recurring costs will be incurred in subsequent years to train new personnel, replace equipment and perform regular monitoring. The stream of costs will range from US$ 10,000 to $40,000 per year during the 20 year life-period considered for the project. **The total "life cycle" cost over 20 years of Scenario 1 is US$ 294,000**.

- Scenario 2: Health, Safety & Spill Prevention *plus* Containment. On the understanding that the benefits of containment can only be fully realized if workers are educated in safety & spill prevention, Scenario 2 includes the activities and costs of Scenario 1 as well as the hard engineering associated with the design and implementation of a containment facility. In the first year, in addition to the Scenario 1 costs, investments are needed to design the containment plan and conduct the engineering works. The first year cost is estimated at US$ 210,000. In subsequent years, operating costs of US$ 28,000/year (average) will be incurred to monitor and maintain the containment infrastructure. **The total "life cycle" cost over 20 years of Scenario 2 is US$ 741,000**.

- Scenario 3: Health, Safety & Spill Prevention *plus* Disposal. Again, on the understanding that the benefits of disposal can only be fully realized if workers are educated in safety & spill prevention, Scenario 3 includes the activities and costs of Scenario 1 as well as the engineering associated with the design and implementation of the disposal plan. Most of the costs are expected to occur during the first year. Remediation of the site will include additional studies to determine in greater detail the extent of the contamination, the removal and shipping of the contaminated material to a disposal facility, and the disposal itself. Even though no costs are expected to incur with regard to the site clean-up after it is completed, operating costs of US$13,500/year will be incurred to monitor environmental and human health and enforce the health and safety plan. **The total "life cycle" cost over 20 years of Scenario 3 is US$ 967,000**.

To compare the costs of the 3 scenarios in a meaningful way, the present values of their respective 20-year cost streams are calculated. Using a 5% discount rate, the present value of costs for Scenarios 1, 2 and 3 are US$ 192,000, US$ 522,000 and US$ 833,000 respectively (Figure 4).

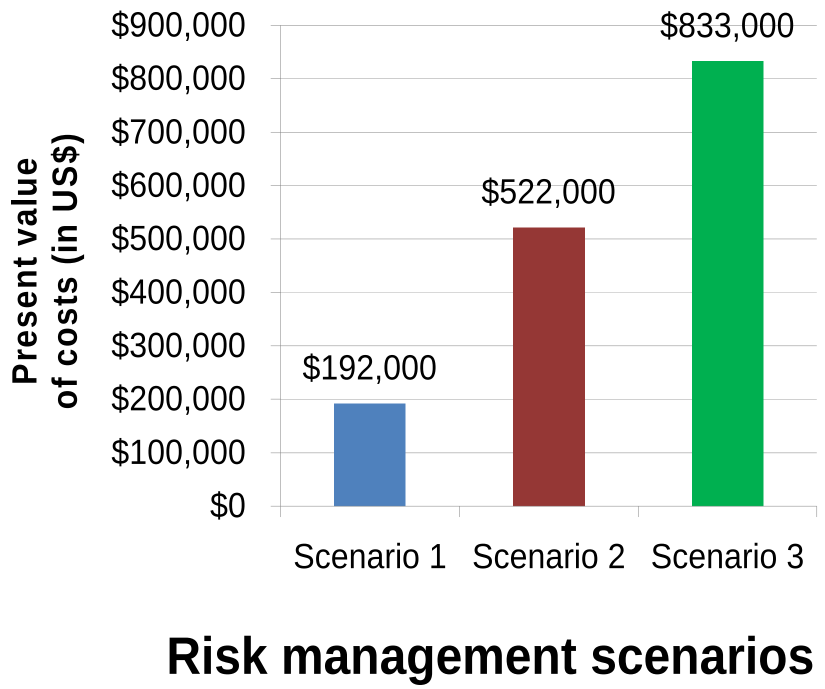
4.2 QUANTITATIVE MEASURES OF HEALTH BENEFITS

DALYs are estimated on a country specific basis; the estimate is derived from ancillary data and standard equations, as presented below.

Estimate of Site-Specific DALYs

Even though the DALY *equations* are simple, they require a large amount of data to be calculated. Lack of nation-specific and site-specific associations of mortalities and health effects necessitate that indirect sources be used to make

Figure 4 Present value of costs of the risk management scenarios.



DALY *estimates*. Fortunately, WHO has estimated DALY rates per 100,000 of population for a long list of causes for all of its member countries (allowing greater international applications and comparisons if desired)[9].

Table 1 presents the DALY rates per 100,000 people for Lao PDR, from all causes (including communicable diseases, non-communicable diseases and injuries).

Not all components of the total number of DALYs are related to a single cause (e.g., POPs exposure or non-POPs chemical exposure). The absence of a scientific, unequivocal relationship between exposure to POPs and specific health impacts prevents one from estimating the DALY rate specifically associated to POPs-related diseases. Attempts at establishing this link based on assumptions, even coming from accepted sources or references, would be tainted with uncertainty.

Box 2 provides an example of the potential flaw in relying on assumptions or findings taken out of the specific context in which they were established.

[9] Although the WHO has provided DALY estimates for 2004 for the world and various subregions, the latest available DALY estimates for individual countries date back to 2002. These estimates are available at http://www.who.int/entity/healthinfo/statistics/bodgbddeathdalyestimates.xls and are the ones used in the present economic analysis.

Table 1 DALY Rates per 100,000 People calculated by WHO (2002).[10]

Global Burden of Disease cause			Lao PDR Republic
All Causes			**40,324**
I.	*Communicable, maternal, perinatal and*		*24,340*
	A.	Infectious and parasitic diseases	10,740
	B.	Respiratory infections	3,660
	C.	Maternal conditions	1,371
	D.	Perinatal conditions (h)	6,663
	E.	Nutritional deficiencies	1,906
II.	*Noncommunicable diseases*		*11,257*
	A.	Malignant neoplasms	932
	B.	Other neoplasms	24
	C.	Diabetes mellitus	157
	D.	Endocrine disorders	95
	E.	Neuropsychiatric conditions	3,183
	F.	Sense organ diseases	795
	G.	Cardiovascular diseases	2,315
	H.	Respiratory diseases	933
	I.	Digestive diseases	1,093
	J.	Genitourinary diseases	212
	K.	Skin diseases	50
	L.	Musculoskeletal diseases	409
	M.	Congenital anomalies	913
	N.	Oral conditions	144
III.	*Injuries*		*4,727*
	A.	Unintentional injuries	3,849
	B.	Intentional injuries	878

10 The WHO provides two types of estimates: one that uses actual mortality rate and one whereby DALY estimates are adjusted for differences in population age distributions through application of age-standardized death rates; Standardization is required when comparing several populations that differ with respect to age because age can largely influence the incidence of disease. This is not the objective pursued in the present study, so the “standard” rate was retained.

Box 2 Uncertainty associated with assuming a quantitative link between exposure to POPs and burden of disease based on ancillary studies.

In a World Bank study entitled *Environment Strategy Papers N.1: Health and Environment*, Lvosvky (2001) considered that **the burden of disease potentially associated with acute and chronic exposure to pesticides and non-point source industrial contaminants in the environment could be estimated as a percentage of the summation of DALYs over 15 diseases,** including: liver and pancreatic cancer, melanomas and other skin cancers, lymphomas and multiple myeloma, endocrine disorders, unipolar major depression, cataracts, nephritis and nephrosis, rheumatoid arthritis, congenital anomalies (excluding spina bifida and congenital heart anomalies) and poisonings across all age groups.

According to Lvosvky (2001), the percentage of the DALYs in these disease categories that can be attributed to exposure to pesticides and nonpoint-source industrial contaminants is assumed to vary between 5% (conservative) and 20% (liberal). The corresponding results for Lao PDR are presented in the table below:

Health impact related to acute and chronic exposure to pesticides and nonpoint-source industrial contaminants		Lao PDR
DALY rate / 100,000 people	*Liberal*	504
	Conservative	126
Share of total DALY rate	*Liberal*	1.3%
	Conservative	0.3%

Lvovsky (2001) provides a rough order of magnitude of the DALY-rates associated with chemical exposure; results were also used for subsequent studies such as the "Social Cost of Chemicals"(Pearce and Koundouri 2003). However, they cannot be applied directly within the context of the POPs Project for the following reasons:

- At a site-specific scale, the relative significance of the various causes of disease may vary significantly from the average established at the country and city level;
- The study considered exposure to a broad category of "pesticides and non-point source industrial contaminants" and "pollutants from fossil fuels", while our assessment is focused on POPs, and specifically PCBs in Lao); using the same assumptions would therefore prove unsuitable as:
  - It may result in overestimating the DALY rates related to POPs exposure: the larger the pool of contaminants considered, the larger the burden of disease is likely to be; and
  - Another consequence of the above is the mismatch between the selection of disease categories retained by Lvovsky as a basis for her estimate and the disease traditionally associated to POPs: for example, cataracts are not cited among the consequences of exposure to POPs, while spina bidfida and diabetes are included among the disease associated to dioxin exposure.

The DALY rate determined by WHO is applicable to the entire population of the countries considered; it can be used to estimate the number of DALYs (total or potentially related to POPs exposure) at specific sites through application of the formula:

$$DALYs_{Site} = \frac{DALYrate_{Country} \times Population._{Site}}{100000} \quad [1]$$

where $Population_{Site}$ is the potentially exposed population at the site under consideration who may benefit from the proposed remediation efforts.

The Hatfield Team estimated during the risk assessment that the potentially exposed population at the SPL site is 2,826 people, based on the data provided by the National Focal Point and National Consultant and field questionnaire survey. This estimate was verified through consideration of site-specific factors - including GIS analysis of human habitation in a 1 km radius of the site - as well as professional judgment regarding the zone of influence of the sites the interaction of workers and non-workers with the site, and potential off-site contaminant exposure pathways associated with the site (Hatfield, 2009a).

Using the site population estimate of 2,826 people, and the total DALY rate provided by the WHO of 40,324 per 100,000 people in Lao PDR, the application of formula [1] gives a total number of DALYs at the SPL site equal to **1,140**.

Estimate of the DALY Value by Country

A monetary value can be ascribed to a DALY to reflect the economic cost of one lost year of "healthy" life due to premature death, poor health or disability. **The value of a DALY is specific to each nation and reflects its economy, people's earning power and local prices.**

The best approach to valuation of DALYs in the POPs Project is that of benefit transfer. Benefit transfer is "*a practice used to estimate economic values for ecosystem services by transferring information available from studies already completed in one location or context to another*"[11]. Therefore, benefit transfer uses an estimate made elsewhere and "adjusts" it for application to the site/nation in question.

The original value of a DALY was determined using the methodology proposed by Lvovsky *et al.* (2000). According to this methodology, the value of a DALY can be obtained by dividing the Value of a Statistical Life (VSL) by the number of DALYs associated with premature death caused by pollutants of concern. The VSL corresponds to the Willingness to Pay (WTP) of a given population to reduce certain kind of risks to which it is exposed.

[11] OECD Glossary of Statistical Terms, p. 69.

In an ideal situation:

- The VSL would be estimated through a study [12]applied specifically to the POPs-related health risks and targeting the population exposed to this risk; and

- The distribution of the risk of premature death caused by POPs-related diseases across the population at the site could be established through a dose-response relationship and/or epidemiological data.

However, none of the above information is available for the present case study, nor can they be obtained easily. As a result, non specific data from ancillary sources must be used.

A reliable estimate of the VSL can be retrieved from a work by Mrozek & Taylor (2002), in which they reviewed more than 40 studies providing over 200 VOSL estimates. The key finding was that VSL estimates range from approximately US$ 1.5 million to US$ 2.5 million (in 1998). Using the mid-point of this range, an average VSL of US$ 2 million in 1998 can be taken as reference. This figure is escalated to reflect price inflation between 1998 and 2008[13], and translates into a VSL in 2008 of US$ 2.64 million.

To obtain the value of a DALY, the VSL must be divided by the number of DALY corresponding to a premature death. This number varies in function of the age at which death occurs, which itself depends on the nature of the risk considered (here, POPs-related health impacts). However, no information is available about age-specific mortality caused by exposure to POPs; and, there is no basis to assume that POP-related diseases would impact a given age class more than another[14]. As a result, the average population is assumed to stand an average loss of 22 DALYs per premature death according to the age-distribution of DALYs.

The value of a DALY in the US, in 2008, obtained in applying the Lvovsky (2002) methodology is therefore US$ 120,000 (2.64 million/22). This estimate needed to be adjusted to reflect the present day situation in Lao PDR. An easily retrievable indicator representative of the differences between Lao PDR and the US is per capita gross national product. It was retained as an appropriate adjustment variable for the DALY value on the grounds that the economic value placed on health benefits by a population can be related to the level of economic prosperity enjoyed by this population[15]. The data used for, and the result of, this calculation are presented in Table 2.

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[12] Based on labor cost, contingent valuation or human capital approaches.

[13] Using the US Bureau of Labor's Department CPI Inflation Calculator - http://www.bls.gov/data/inflation_calculator.htm.

[14] In fact, the duration and intensity of exposure may be more relevant than the age of the receptor.

[15] This is a purely economic rationale supporting the implementation of a project analysis technique, and therefore leaving no room for ethical considerations. However, it is strongly emphasized that the value of a human life outside this specific, theoretical context does not depend on the geography or level of prosperity of the population concerned.

Table 2 Calculation of the DALY value for Lao PDR.

Variable	Value	Source
Value of a statistical life in US, 1998	US$ 2,000,000	Mrozek & Taylor (2002)
Adjustment to inflation		
Value of a statistical life in US, 2008	US$ 2,640,000	US Bureau of Labor's Department
Number of DALY for a premature death	22	WHO
Value of a DALY in US, 2008	US $120,000	
Benefit Transfer Conversion		
GNI/capita, PPP – US	US$ 46,040	World Development Indicators database
GNI/capita, PPP – Lao	US$ 1,940	World Bank, revised 17 October 2008
Value of DALY in Lao PDR in 2007[16]	**US$ 5,056**	-

4.3 ECONOMIC ANALYSIS

The purpose of the economic analysis is to estimate the benefits required for each scenario so that they have a Net Present Value ≥0, following the steps outlined in Section 3.3.

Estimate of the Yearly Benefits Required, Expressed in Dollars

The first step of the analysis is to determine the stream of benefits that meets the conditions defined in the methodology, as presented below:

- The benefits are the same each year;
- The benefits occur from Year 2 to 20 of the project; and
- The present value of the benefits equals the present value of costs (determined in Section 4.1.3).

The annual benefits required to cover the costs are US$ 16,696 for Scenario 1, US$45,346 for Scenario 2, and US$ 72,367 for Scenario 3.

Estimate of Yearly Benefits Required, Expressed in DALY

The second step of the analysis is to convert the value of benefits expressed in dollars terms into a DALY number. This requires dividing the yearly benefits by the value of a DALY in Lao PDR.

[16] The inflation rate for 2008 is not published on the World Bank website at the date the analysis was conducted. The value estimated for 2007 is therefore the most recent that could be calculated based on the data available.

Using a DALY value for Lao PDR of US$ 5,056, the required annual benefits can be expressed as 3.3 DALYs for Scenario 1, 9.0 DALYs for Scenario 2, and 14.3 DALYs for Scenario 3.

Estimate of Yearly Benefits Required, Expressed in Percentage DALY Reduction

The third step of the analysis is to represent the number of DALYs calculated above as a percentage of the total DALYs at the SPL site, so as to determine the reduction of health impacts that the scenarios need to achieve.

Expressed as a percentage of total DALYs at the SPL site, a DALY reduction of 0.3% (Scenario 1), 0.8% (Scenario 2) and 1.3% (Scenario 3) is required to cover mitigation costs.

Summary of Results

Table 3 summarizes the results of the economic analysis for each of the proposed risk management scenarios (see Appendix A3 for detailed calculations).

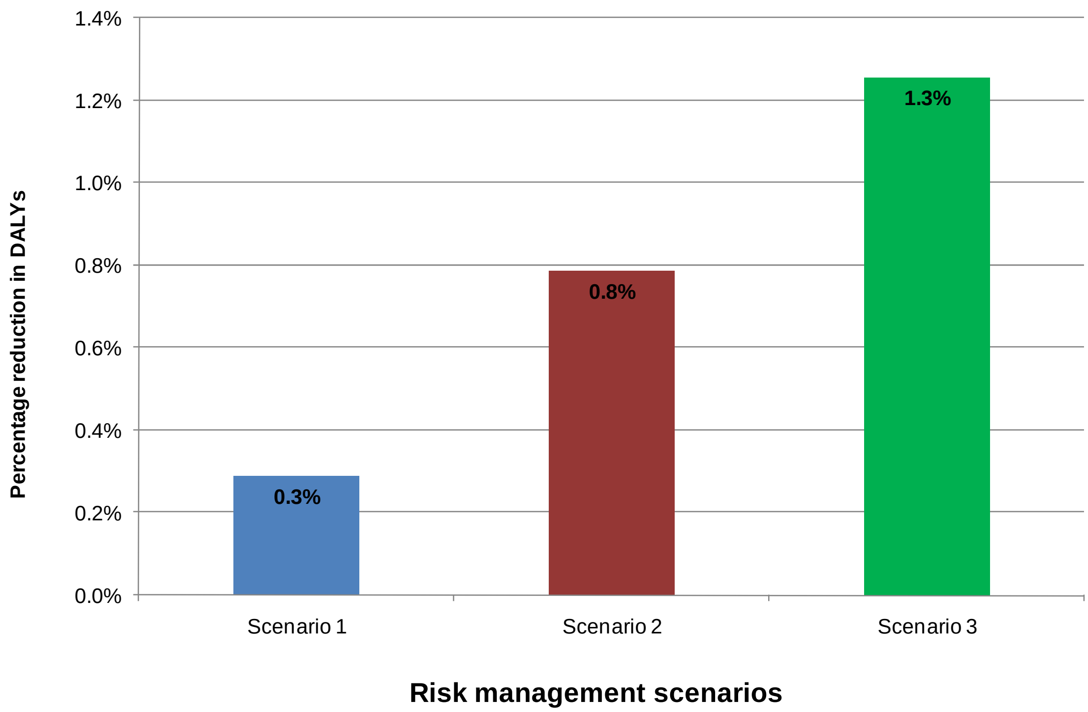
The benefits have been calculated so that the present value of benefits is equal to the present value of costs (i.e. so that the net present value is equal to zero). The benefits are expressed in dollars terms, in DALYs, and as a percentage of the total DALYs on the site.

Table 3 Results of the economic analysis, SPL Site, Lao PDR.

Scenario	**Present Value of Costs**	**Benefits Required to Achieve NPV = 0**		
		Annual benefit (year 2 to 20)	DALYs to be "saved" per year	Percentage reduction of total DALYs/year
Scenario 1	$192,168	$16,696	3.3	0.3%
Scenario 2	$521,929	$45,346	9.0	0.8%
Scenario 3	$832,930	$72,367	14.3	1.3%

Figure 5 illustrates the benefits required for each scenario expressed as a percentage of the total DALYs on the site, that is, the minimum positive health impacts that the scenarios need to achieve to be worth implementing from an economic perspective.

Figure 5 Positive health effects (percentage reduction in DALY) required to cover the costs of each risk management scenario.



4.4 DISCUSSION

4.4.1 Probability of Achieving the Required Health Benefit

The results obtained from the economic analysis are estimates of the minimum health benefits required to cover the costs of each proposed risk management scenario. What decision-makers want to know is whether one can reasonably expect these reductions in DALYs to be achieved. Answering this question poses a major challenge for the reasons outlined below[17]:

- The actual reduction of exposure achieved by the proposed risk management scenarios is not known (although this could be ascertained through long-term monitoring);
- There is no epidemiological basis to confirm and quantify the link between a reduction in exposure to POPs and positive health effects at the site;

[17] Such limitations and uncertainties are not specific to the present POPs Project. In fact they are a common challenge in the economic analysis of projects or policies aiming to reduce the health impacts of chemicals; they are for example highlighted by Pearce and Koundouri in "the Social Cost of Chemicals"(2003).

- There is a wide range of uncertainty associated with the monetization of health benefits; a change in DALY value would have an influence on the estimate of number of DALYs to be saved; and

- The cost estimates are based on roughly defined scenarios (including engineering measures that have not been subject to detailed design) and unit prices determined mostly through desktop study. There is consequently a margin of error associated with these estimates.

As a result, the best approach for interpreting the results is to provide a qualitative assessment of the **probability** that the minimum benefits can be achieved. Until a site–specific assessment is made by a local epidemiologist, this requires drawing on ancillary studies or data established in similar contexts.

Pearce and Koundouri (2003; Section 4.2, p. 28,) used the assumptions made by Lvovsky (2001) to estimate that the DALY potentially "targeted" by REACH account for 0.6% to 2.5% of the total DALYs for UK and Europe. Then, they assumed that the implementation of REACH will result in a 10% decrease in the targeted DALYs. In other words, the authors stated that it is reasonable to expect that an investment in reduced chemicals exposure may be expected to result in a decrease in DALYs in the range of 0.06% – 0.25%. This range will be used as the benchmark against which the proposed investments in scenarios 1, 2 or 3 at the SPL warehouse in Vientiane will be compared.

Comparing the results highlighted in Table 4 with the benchmark allows the following conclusions:

- <u>Scenario 1</u>: To justify the investment in Scenario 1, an annual saving of 3.3 DALYs or 0.3% of total annual DALYs in the exposed population is required. This percentage compares favorably with the benchmark range, especially when one takes into account that the REACH program is a policy not a targeted investment project as proposed for the SPL site. We may therefore be confident that an investment in "breaking the pathway" through worker education may be justified on human health impact grounds alone;

- <u>Scenario 2</u>: To justify the investment in Scenario 2, an annual saving of 9.0 DALYs or 0.8% of total annual DALYs in the exposed population is required. This percentage falls outside the benchmark range of the REACH project; however, Scenario 2 is likely justified on human health impacts alone. To verify that the investment is justified requires the inclusion of other economic, environmental and social benefits, the estimation of which is beyond the scope of this project; and

- Scenario 3: To justify the investment in Scenario 3, an annual saving of 14.3 DALYs or 1.3% of total annual DALYs in the exposed population is required. This percentage falls well outside the benchmark range of the

REACH project. Even taking into account that the benchmark range is a minimum, it appears certain that for the investment to be justified requires the inclusion of other economic, environmental and social benefits, the estimation of which is beyond the scope of this project.

Several arguments balance the conclusions that to justify the investments in Scenarios 2 & 3 requires the inclusion of other benefits:

- Pearce and Koundouri (2003) recognized that a 10% reduction in health impacts through REACH represents a fairly low assumption;

- The risk management scenarios are aimed specifically to reduce exposure to POPs (by removing the pathway between the contaminants and the receptors in the case of Scenario 1; or removing partially or entirely the source contaminant in Scenario 2 and 3). REACH achieves this objective through indirect measures (namely the implementation of procedures of registration, evaluation and authorization of chemicals). Therefore the health effects can be expected to be greater for the risk management scenarios than through the implementation of a REACH-like policy; and

- The impacts of the risk management scenarios are measured on the receptors only (i.e. on the local population that is known to be exposed to the contaminants). Because of this narrow focus, the *relative* health effects (expressed in percentage reduction of DALYs) at the SPL site are likely to be more significant than for a large-scale program, where the effects are assessed over the general population. In the latter case, the impacts are measured on people that may or may not be exposed to contamination - and thus may or may not benefit from the reduction thereof – so they are smaller "on average" than the impacts measured on the exposed population only.

Based on the above, it is clear that substantial uncertainties at the various stages of the assessment preclude a definitive conclusion. In spite of this, based on a qualitative interpretation of the results, it seems fair to consider that: (i) the results of the economic analysis **support the implementation of Scenario 1, as the benefits required to cover the costs appear achievable;** and (ii) taken alone, these results do not imply the objective conclusion that the implementation of Scenario 2 and 3 is economically sound. Therefore, the consideration of other benefits becomes critical for decision-makers in their decision to proceed or not proceed with the investments required for these two scenarios.

4.4.1.1 Consideration of Other Benefits

The economic analysis focused on estimating the minimum positive impact on human health required to cover the costs of the risk management scenarios proposed at the SPL site. It is clear, however, that the positive impacts of

Scenarios 1, 2 and 3 go beyond human health impact as measured in DALYs saved per year (see Appendix A1). Other potential benefits include, but are not limited to:

- Increase in agriculture and aquaculture: contaminated runoff originating from the SPL enters the drainage system, which discharge into rice fields and man-made ponds in the southeast corner of the compound (See Appendix A1). The local population relies on agriculture and fisheries as their principal food sources. Fish exposure to chemical contamination may result in impacts to habitat and reproductive success. Removal of contamination is expected to improve breeding habitat ands therefore lead to increased fish production. As well, use of non-contaminated water for irrigation is expected to improve the quality of the rice harvested locally; that will represent a benefit to the rice growers, whether it is used for self consumption or commercialized[18].

- Increase in land value: The location of the site in an important residential, business and political centre of the capital city of Lao PDR, Vientiane, indicates that there must be a sustained demand for the land, with correspondingly high real estate values. It is reasonable to assume that these values could be higher still if the POPs hotspot at SPL were cleaned up, since the suitability of the land for housing or other uses (e.g., commercial, storage) would improve. Increased land value in vicinity of the SPL site could therefore be seen as an additional benefit of the project. However, because the real estate market is likely to be characterized by inelastic demand, such increase in land value may result from a displacement of demand from another area rather than translate in a rise of the overall demand. Therefore, the risk cannot be excluded that the project's impact on land value be a transfer of benefits, rather than an actual benefit.

It must be emphasized that these benefits remain to be quantified because of the particular circumstances of the project; namely, the absence of cause-effect relationships and the limited scope of the project and not because of their intrinsic characteristics. Similar environmental benefits can be quantified in different project settings. Keeping in mind *"that some environmental benefits cannot be quantified … does not mean that they should be ignored"* (World Bank 1998), the significance of these benefits is taken into consideration qualitatively as part of the interpretation of results of the economic analysis.

Although their significance remains to be quantified, other benefits are considered as an important additional factor contributing to the economic viability of risk management investments at the hot spots studied under the POPs Project.

[18] Improved water quality will also result in benefits through reduced exposure through the food chain, but such benefits are already accounted for in the valuation of health benefits.

4.4.2 Risk

A CBA of a proposed investment involves a look into an uncertain future. It is based on the analyst's best estimates about the quantities and prices of inputs required and outputs achieved. It is inevitable that some unforeseen events will take place that will influence the project as a whole and costs and benefits in particular. A discussion of the risks that the proposed project is likely to face is, therefore, appropriate. As with benefits, some risks are quantifiable while others may only be described using such terms as "nil", "minimal", "moderate" and "major".

4.4.2.1 Unquantified Risks

The risks that the SPL project may face are described and qualified in Table 4.

Table 4 Unquantified Risks.

Type of Risk	Concern	Status on SPL Project
Engineering / Technology	Does the success of the project depend on the use of tried or untried engineering techniques or technology?	Engineering & technology in Scenarios 1, 2 & 3 is well-known. Engineering Risk: Minimal
Political	Is political stability an issue of concern?	There is no political concern, either associated with the location of the hotspot (Vientiane) or the nature of the project (human health). Political Risk: Nil
Input Availability	Are the required inputs to implement Scenarios 1, 2 & 3 easily available at competitive prices?	All inputs are easily available with the possible exception of highly trained labour. Input Risk: Minimal Skilled Labour Risk: Moderate
Markets for Outputs	Can the output be sold? Are markets, either local, domestic or international sufficiently large to absorb the output of the project?	The output or benefit is improved human health that is enjoyed by the beneficiaries and is not sold. Output Risk: NIL
Currency Risk	Will foreign currency fluctuations adversely affect the sale of outputs or a profitable bottom line?	There is no output to sell internationally. Currency Risk: Nil
Environmental	Does project implementation have adverse environmental consequences?	On the contrary, the project is aimed at POPs clean-up. The only "risk" is that unquantified environmental benefits will exceed quantified human health benefits. Risk of Adverse Impact: Nil
Social	Is the project likely to adversely affect one social group (e.g., women) more than another?	Environmental impact is likely to affect groups such as children more than their parents; the project will have a positive impact on vulnerable groups. Social Risk: Nil

4.4.2.2 Quantifed Risks: Sensitivity Analysis

There is always the risk that the analyst's "best guess" concerning input and output prices and quantities will prove to be inaccurate, thereby affecting the bottom line of the project. To gain some insight into the likely impact of unforeseen developments on a project, it is wise to conduct a sensitivity analysis to see how the major economic measures would be affected by changes in major cost or benefit variables. Sensitivity analysis uses the concept of "elasticity" to compare the response of a dependent variable (e.g., NPV) to a fixed change in an independent variable (e.g., capital cost, revenue, etc.). If the dependent variable (e.g., NPV) decreases by a greater percentage than the increase in the independent variable (e.g., cost) the sensitivity indicator (SI) is greater than 1 and the response to the fixed change is considered to be "elastic" or "sensitive. If the SI is less than 1, the response to the fixed change is considered to be "inelastic" or "insensitive. A project with high sensitivity indicators would be considered a riskier undertaking than one with low sensitivity indicators.

At the SPL project level, sensitivity analysis is a useful quantitative tool to appraise how changes to key variables such as capital or operating costs or the unit DALY value are likely to impact the outcome of the analysis, as measured by NPV, the standard performance criteria used in a cost-benefit analysis. However, because of the modified approach to CBA that was employed in this analysis (in which NPV was set to zero and the number of DALYs was manipulated), sensitivity indicators will be estimated using the number of DALYs as the dependent variable.

The sensitivity indicator equation is calculated as follows:

$$\frac{\%\text{ change DALYs}}{\%\text{ change in Cost}} = \frac{(D_2 - D_1) / ((D_1 + D_2)/2)}{(C_2 - C_1) / ((C_1 + C_2)/2)}$$

Where: C_1 = Cost $_{\text{estimate}}$ before 10% increase

C_2 = Cost estimate after 10% increase

D_1 = # DALYs to meet NPV = 0 with C_1

D_2 = # DALYs to meet NPV = 0 with C_2

The results of the sensitivity analysis calculations are summarized in Table 5.

Table 5 Sensitivity Analysis.

Scenario	10% Increase in Capital Cost	10% Increase in Operating Cost	10% Decrease DALY Value
Scenario 1	No cap cost	1.00	1.11
Scenario 2	0.26	0.76	1.11
Scenario 3	0.72	0.30	1.11

The results are interesting and several comments are in order.

- *Scenario 1*: Scenario 1 has no capital costs, only operating costs. In other words, increasing operating costs by 10% results in an increase of total cost by 10%. Not surprisingly, a 10% increase in total cost with NPV held at zero requires a 10% increase in the number of DALYs required to cover the new cost and an SI = 1.00 is the result. Therefore, the project is of neutral sensitivity with respect to cost overruns. On the benefit side, a 10% decrease in the unit value of a DALY (e.g., to 90% of its former value) requires an offsetting 11% increase in the number of DALYs (e.g., 1.00 / 0.90 = 1.11) to maintain sufficient revenues to cover costs. SI = 1.11 indicates that the project is mildly sensitive to changes in the unit value of a DALY;

- *Scenario 2*: At US$ 597,000, approximately 80% of the total cost ($USD 741,000) of Scenario 2 is operating cost with the remaining 20% being capital cost. This explains why the SI for changes in operating cost (0.76) exceeds that of capital cost (0.26) by a considerable margin. Therefore, Scenario 2 is insensitive to changes in either capital or operating costs. As was seen with Scenario 1, the project is mildly sensitive to changes in the unit value of a DALY; and

- *Scenario 3*: At US$ 622,000, approximately 64% of the total cost (US$ 966,000) of Scenario 3 is operating cost with the remaining 36% being capital cost. This explains why the SI for changes in capital cost (0.72) exceeds that of capital cost (0.30). Scenario 3 is insensitive to changes in either capital or operating costs. As seen with Scenario 1, the project is mildly sensitive to changes in the unit value of a DALY.