# CHEMOBS SYNTHESIS REPORT

## Results of Calculators Pilot Testing

Integrated Health and Environment Observatories for the Sound Management of Chemicals and Waste in Africa (GEF ID 9080)

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# Contents

This report was written by Dr Bret Ericson and Dr Sheila Willis for PAN-UK. It covers the reporting period 17th August 2021 – 30th April 2022.

# Executive Summary

The report describes the development, implementation and results of two calculators developed as part of the ChemObs project (GEF ID 9080). The first calculator – Risk and Vulnerability – accepts site specific information for contaminated areas and outputs a relative ranking of ecological and human health risks. The second – Economic – accepts chemicals exposure data for different populations and outputs estimated attributable productivity losses in 2019 USD.

The calculators were developed by the NGOs PAN-UK and Pure Earth over the period 2017–2022 and utilised by national consultants in 9 different African countries. Calculator development was based on the findings of country visits and regional workshops. Implementation was supported through a series of guidance documents, seminars and online tutorials. Revisions were made in an iterative process over the project period in response to field trials and to the comments of independent peer-reviewers.

Of the 9 project countries, 8 submitted at least one completed calculator. Six countries in total managed to complete both calculators. In general, the results show the existence of adequate data and technical expertise at the country level to support the robust calculation of health and ecological risks attributable to chemicals. Challenges encountered include those related to operational considerations and data availability.

# Introduction

The overall Objective of the ChemObs project (GEF ID 9080) is '[t]o contribute to improved health and environment through strengthening national and regional institutions, and implementing priority chemicals and waste related interventions in nine targeted African countries: Ethiopia, Gabon, Kenya, Madagascar, Mali, Senegal, Tanzania, Zambia, Zimbabwe. The project is structured around four overarching components: (1) Strengthening capacity [for chemicals management]; (2) Action plan development; (3) Plan implementation; and (4) Monitoring and evaluation. The work described in this report relates to Component 2, specifically Output 2.2: Identification of population sub/vulnerable group needs that are particularly exposed to chemicals and Output 2.3: Benefits and cost of action to mitigate risks and specific interventions are defined and compared to the estimated costs of inaction.

Two international NGOs, PAN-UK and Pure Earth (USA), were contracted to develop a relative ranking tool to assess the vulnerability of populations living near hazardous waste sites (PAN UK) and a tool to calculate chemicals attributable productivity losses (Pure Earth). These two tools – the 'risk and vulnerability' and 'economic' calculators are described in more detail below. The purpose of this report is to finalize both calculators and synthesize project results. It is not intended as a detailed technical manual or description of the tools, which is provided separately as 'User Manuals.[1]

[1] Available at the following link: https://1drv.ms/u/s!AjyKoJoBZuIC0QDI-Q2wVsadVeeR?e=6U14Ki

# Purpose of the calculators

Given the paucity of work in this area, these models are intended as a 'proof of concept' of tools that – following further improvement, review and testing – could be used in addressing significant and credible risk to human health and the environment.

## Purpose of the economic calculator

The purpose of the economic calculator is to approximate the Cost of Inaction associated with chemicals exposures in the 9 project countries. In the current approach this is done through the estimation of attributable Disability Adjusted Life Years (DALYs), Full Scale Intellectual Quotient (IQ) decrement, and associated economic costs resulting from chemicals exposure.

The calculator assesses chemicals exposure across four different pathways: dietary, dust, soil and water. Users enter known chemicals concentrations for different exposed populations, along with other descriptive characteristics such as age, geography and certain intake parameters (e.g. diet and water consumption). The calculator then uses these inputs to approximate attributable disease and associated productivity losses.

The cost of DALYs is quantified as the annual cost of lost productivity due to morbidity attributable to chemicals exposure. Put differently, it represents lost earnings due to sick days or due to working while sick in a given year. The cost of IQ decrement is quantified as the total future productivity losses attributable to chemicals exposure. Put differently, the value represents decreased productivity and therefore lost earnings across the entirety of one's life because of reduced intellectual capacity.

Lost productivity due to DALYs thus represents a rate, analogous to a 'flow' in economics or 'incidence' in public health. Lost productivity due to IQ represents a snapshot of estimated future losses at a given point in time, analogous to a 'stock' in economics or 'prevalence' in public health. The two are therefore fundamentally different, cannot be summed, and must always be reported separately.

The calculator accepts different types of data inputs, including environmental and biological sampling data. To allow for this level of flexibility in the model, a number of assumptions are employed at different stages. The assumptions are based on existing studies, surveys, reports, or expert opinion. The model is integrated into an accompanying Microsoft Excel workbook which automates the calculations. Associated methods and step-by-step guidance documents are provided separately[2].

The calculator is not intended to produce a definitive calculation of health and social consequences of chemicals exposure. Rather it presents an indicative estimate based on the best available environmental analysis data, established dose response relationships and standard approaches to economic valuation.

[2] Available at the following link: https://1drv.ms/u/s!AjyKoJoBZuIC0QDI-Q2wVsadVeeR?e=6U14Ki

## Purpose of the Risk and Vulnerability Calculator

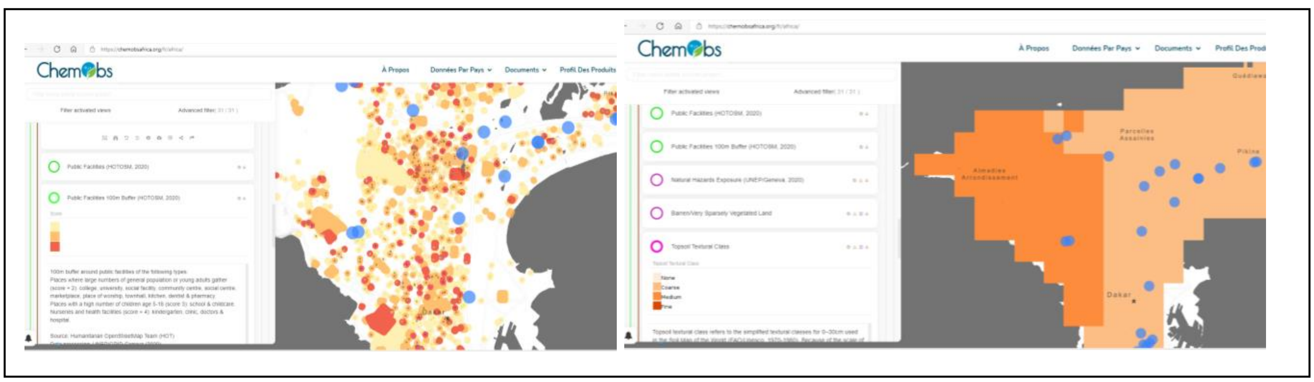
The Risk and Vulnerability Calculator is a decision-making tool designed to support national authorities to prioritise certain contaminated sites for risk reduction. It can support broader policy decisions concerning chemicals management and it would be of value to project managers who are engaged in planning risk reduction interventions at contaminated sites. It is designed to draw on a wide range of publicly available data about the contaminated sites in order to improve the quality of the calculations without increasing the burden of data collection for countries. It also offers countries the opportunity to incorporate their own more recent / accurate data, if available.

The target audience is expected to have concerns about one or a series of sites varying from inadequately contained chemicals stocks that are stored in poorly maintained stores, to sites that clearly show signs of soil contamination. A novel use has been added to the calculator to include pesticides in use, but this part is more experimental at this stage.

Only the minimum of data concerning the type, quantity and condition of the data needs to be gathered at national level. The remaining information required for the calculations can be drawn from publicly available sources. The calculator is supported by the MAPX UNEP/GRID-Geneva web mapping platform system which offers a rich array of data relevant to the sites as well as a display of summary results.

The tool is not designed to support the site assessment process. Existing tools are already available for this purpose e.g. FAO Environmental Management Toolkit for Obsolete Pesticides[3]

*Figure 1. Examples of types of data made available in MAPX showing proximity of contaminated sites (marked in blue) to high risk public buildings, left, and soil type , right*




[3] [Obsolete Pesticides: Resources (fao.org)]()

The calculator is explicitly not intended to produce a definitive calculation of health or environmental risk, but rather is intended to provide a relative calculation of risk based on the best available information. It is expected that higher scoring sites will be prioritised for action.

Although the calculator provides summarised scores for risks to human health or environment in order to aid simple prioritisation for intervention, it also brings together a wide range of information about the contaminated sites and the pollutants that could add value to the assessment and planning process. It helps to identify stores where repacking of chemicals is a priority and others where flooding is a risk, for example.

The calculator could also be used as a monitoring tool to track the reduction in risk scores resulting from interventions, or to predict the impact on risk score from a particular intervention. It also allows decision makers to look at summary information across a range of sites to identify common patterns. The calculator can help to identify recurrent scenarios at multiple sites that may require a common approach to reduce risks and develop prevention measures (see results from Senegal and Kenya for examples).

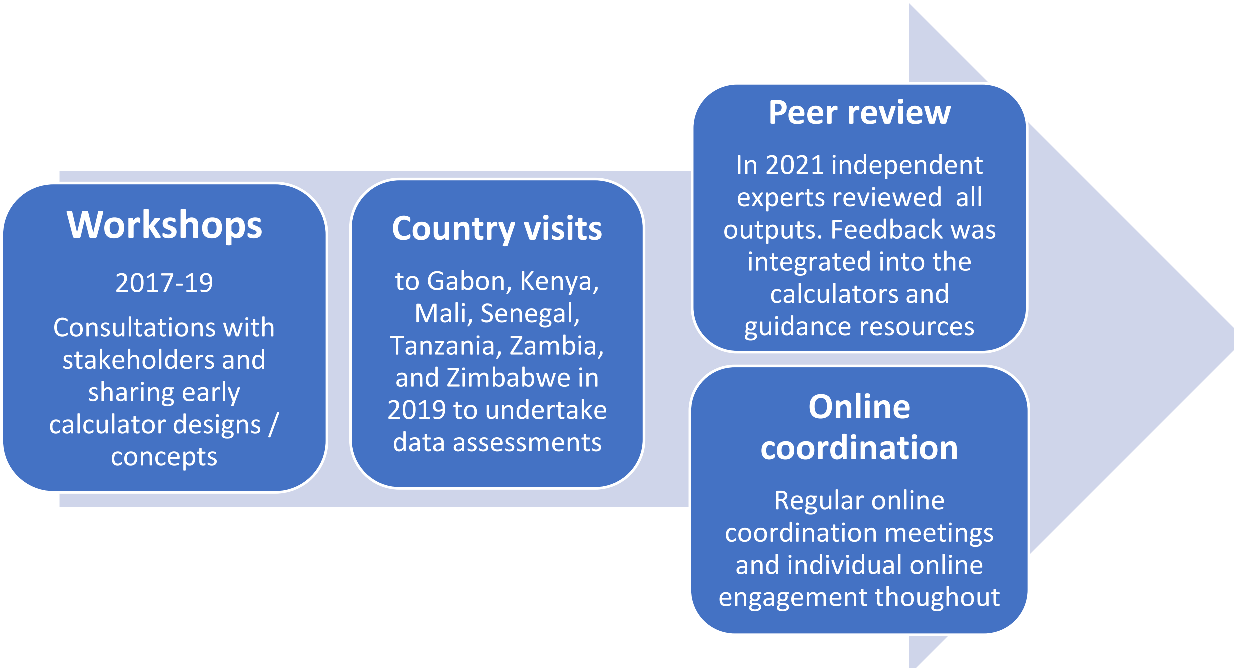
## Calculator Development and Implementation

### Summary

The calculators were developed and refined over the period 2017–2022. The process involved substantial engagement with the countries through regional workshops, country visits and online seminars and meetings. The main purpose of country visits was to identify and characterise sources of data that could be used subsequently in the calculators (see Annex1). The calculators were utilised by national consultants from December 2019 – December 2021 with the support of international experts. The results of those calculations are presented in this report. The international consultants have made themselves available to national staff and consultants for individual online support and discussion throughout the term of this consultancy. All countries have availed themselves of this support. Peer review by external experts was carried out in parallel. Comments from the reviewers and national consultants were integrated through an iterative process.

The international consultants presented the tools to a wider audience in the Pesticide Discussion Forum run by the University of Cape Town.

*Figure 2. Calculator Development Process*




## Peer Review

### *Economic calculator*

Two Economists from the Swedish NGO Environment for Development (EfD) were engaged for the purpose of reviewing the economic calculator. EfD is a global network of environmental economics research centres founded in 2007 and currently comprised of more than 200 economists based in the Global South. For the purpose the review, Daniel Slunge (University of Gothenburg) and Richard Mulwa (University of Nairobi) were engaged. Both individuals had been consulted by Pure Earth during the development of the economic calculator and were familiar with the project. The reviewers were tasked with evaluating the economic calculator and supporting documentation in the style of an academic journal review. Thus comments were organized from general to specific. The consultant ToR, peer review, and formal response are attached as Annex 2. In general comments were supportive of the overall approach, underlying assumptions and presentation.

### *Risk and Vulnerability Calculator*

PAN-UK engaged two experienced international consultants in chemicals management to review the Risk & Vulnerability calculator and associated guidance documents. The review provided an independent assessment of whether the tool was effective for the intended purpose, whether it adds valuable functionality compared to existing tools, to validate the calculations themselves and suggest improvements either to the calculator or associated guidance resources.

The consultants considered that calculations are sound and based on established methodology. They perceived added value for the tool and considered that it could be of value to international agencies as well as national decision makers and project managers. New features / content were proposed for both the calculator and the guidance, as a result of which seven new chemicals were added to the calculator along with new features to aid interpretation and new guidance resources.

The reviewers noted that the manual completion of the calculator is time consuming and considered that it would be much more likely to be used if it was automated in the MAPX system (this had already been proposed by the international consultant and the GRID/MAPX team developed outline plans and budgets for this in 2020).

It was pointed out that each chemical at a site is treated separately and then a total score for each site is a simple summation of scores for individual chemicals. An increasing body of evidence shows that mixtures of chemicals can interact and increase risks even further. While it would be straightforward to increase the risk score where certain combinations of chemicals are present, unfortunately the underlying interactions and impact on risks are complex and poorly understood and so this issue has not been addressed in the calculator at this time.

The consultant ToR, peer review, and formal response are attached as Annex 3.

# Methodology

## Economic Calculator

The economic calculator assesses chemicals exposure across four different pathways: dietary, dust, soil and water. Users enter known chemicals concentrations for different exposed populations, along with other descriptive characteristics such as age, geography and certain intake parameters (e.g. diet and water consumption). The calculator then uses these inputs to approximate attributable disease and associated productivity losses.

The cost of DALYs is quantified as the annual cost of lost productivity due to morbidity attributable to chemicals exposure. Put differently, it represents lost earnings due to sick days or due to working while sick in a given year. The cost of IQ decrement is quantified as the total future productivity losses attributable to chemicals exposure. Put differently, the value represents decreased productivity and therefore lost earnings across the entirety of one's life because of reduced intellectual capacity.

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The calculator accepts a variety of data inputs, including environmental and biological sampling data. To allow for this level of flexibility, a number of assumptions are employed at different stages in the model. The assumptions are based on existing studies, surveys, reports, or expert opinion. The model is integrated into an accompanying Microsoft Excel workbook which automates the calculations. Associated methods and step-by-step guidance documents are available separately[4].

## Risk and Vulnerability Calculator

The calculator uses the common model of Source-Pathway-Receptor as the basis for understanding and assessing risks at a site. This model is consistent with risk screening approaches used internationally (by USEPA, WHO, FAO and others).

Three tools were used as a basis for developing the Risk and Vulnerability Calculator:

- The Blacksmith Index for contaminated sites[5]
- The FAO EMTK methodology for contaminated sites[6]
- The Toxic Load Indicator for pesticides in use[7]

A comparison of these tools with the R&V calculator is provided in the 'Note to Project Managers'[8]. The OECD working paper titled 'Chemical risk assessment and translation to socio-economic assessments'[9] also informed this process.

We have added new variables that have not been used by existing methodologies, where data sets are relevant, available and are compatible with MAPX. This combination with MAPX offers some powerful possibilities in terms of mapping the relative risks in future and automating the bulk of the calculation process.

The calculator is organised into the following sets of information, which is summarised in Figure 3:

- **Source** information identifies the chemical pollutant(s) and an estimation of the scale of release of the chemical into the environment. The data required includes the volume, concentration, conditions of storage and size of contaminated area. This information is drawn from location-specific site questions . In an experimental use of the calculator we considered pesticides in use as well as obsolete chemical pollutants.

- **Intrinsic properties** that relate to the hazard from each chemical are included in the 'data sheet' in the calculator. They include measures of chronic impacts on health (carcinogenicity, reproductive and developmental toxicity) as well as acute toxicity. In addition, the calculator includes toxicity to honeybees and aquatic species. Physical properties are addressed e.g. solubility, persistence, volatility. All parameters can be reviewed in the 'data' page of the calculator.

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[4] Available at the following link: https://1drv.ms/u/s!AjyKoJoBZuIC0QDI-Q2wVsadVeeR?e=6U14Ki

[5] The Blacksmith Index; Caravanos, Jack & Gualtero, Sandra & Dowling, Russell & Ericson, Bret & Keith, John & Hanrahan, David & Fuller, Richard. (2014). A Simplified Risk-Ranking System for Prioritizing Toxic Pollution Sites in Low- and Middle-Income Countries. Annals of Global Health. 80. 10.1016/j.aogh.2014.09.001.
(PDF) A Simplified Risk-Ranking System for Prioritizing Toxic Pollution Sites in Low- and Middle-Income Countries (researchgate.net)

[6] FAO Environmental Management Toolkit for Obsolete Pesticides (EMTK) series (later adapted by UNEP/GRID-Geneva) http://www.fao.org/3/i0473e/i0473e.pdf

[7] The Toxic Load Indicator by Lars Neumeister
https://www.researchgate.net/publication/319259870_Toxic_Load_Indicator

[8] Available at the following link: https://1drv.ms/u/s!AjyKoJoBZuIC0QDI-Q2wVsadVeeR?e=6U14Ki

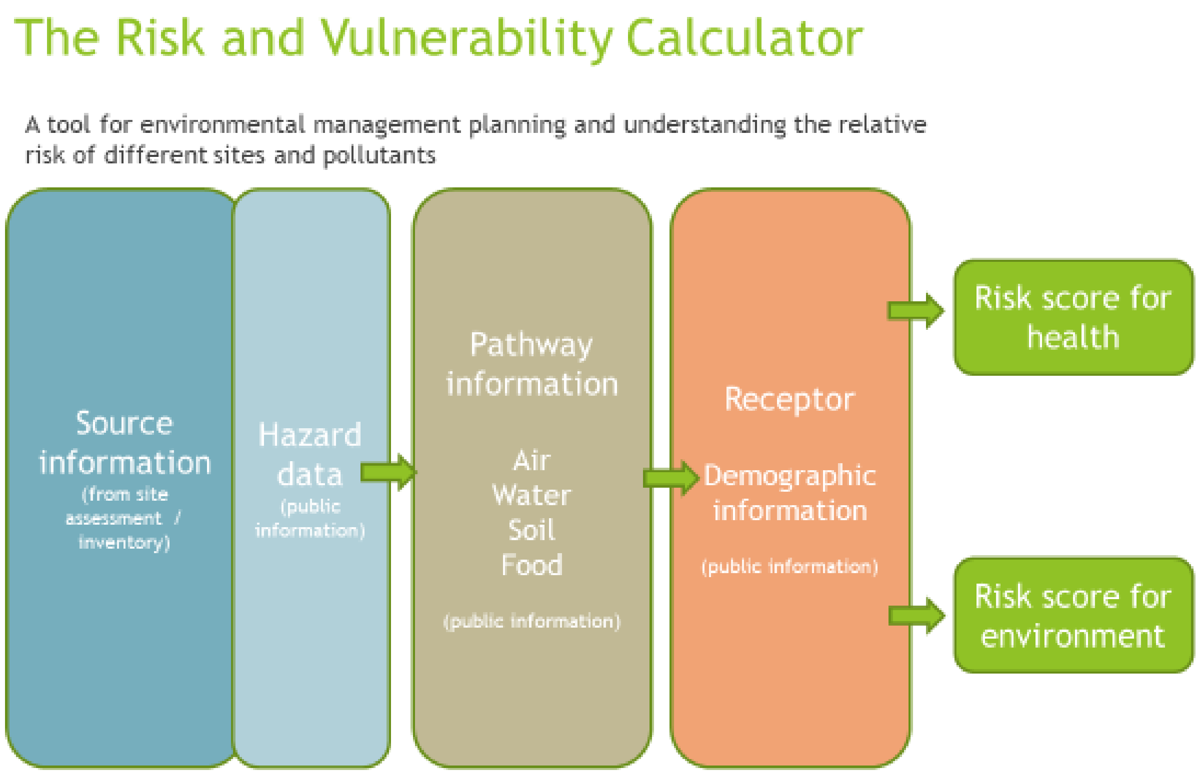
[9] Chiu, W. (2017), "Chemical risk assessment and translation to socio-economic assessments", OECD Environment Working Papers, No. 117, OECD Publishing, Paris. http://dx.doi.org/10.1787/a930054b-en

- **Pathway** The pathway describes the route to exposure to the chemical, either directly when handling it or in soil, dust, water or air. By separating the calculations into different 'pathways' we are able to combine relevant indices in the final calculations e.g. For the water pathway, proximity to open water sources and annual precipitation are included. In the final calculation they are combined with relevant intrinsic properties, such as solubility (see above), to contribute to a final score.

- **Receptor** information concerns the population at risk of being exposed to pollution from the site. The calculator separates the human population into three groups; people working directly on the site; people living within 100m of the site perimeter; people living 100-500m from the site. These are further disaggregated according to age and gender and contribute to the 'health score'. Receptors also include other key species, which are included in the 'environmental score'; in this case we considered aquatic organisms (*Daphnia* spp) and honeybees. These were chosen on the basis that data is available for these organisms for a wide range of chemicals. Also, a strong correlation exists between Daphnia species (mostly *Daphnia magna*) and both fish species (mostly rainbow trout [*Oncorhynchus mykiss*] and bird toxicity (mostly *Colinus virginianus*).

Along with numerical values for each variable, they are assigned a weighting in order to reflect their contribution to risk in the final score e.g. children and women of reproductive age are weighted more heavily because of their greater vulnerability to health impacts from chemical pollutants. The full list of variables and their weightings are provided in Annex 4. A full description of each calculation is provided in Annex 5

*Figure 3. The structure of the Risk and Vulnerability Calculator*




## *Sources of information for the R&V calculations*

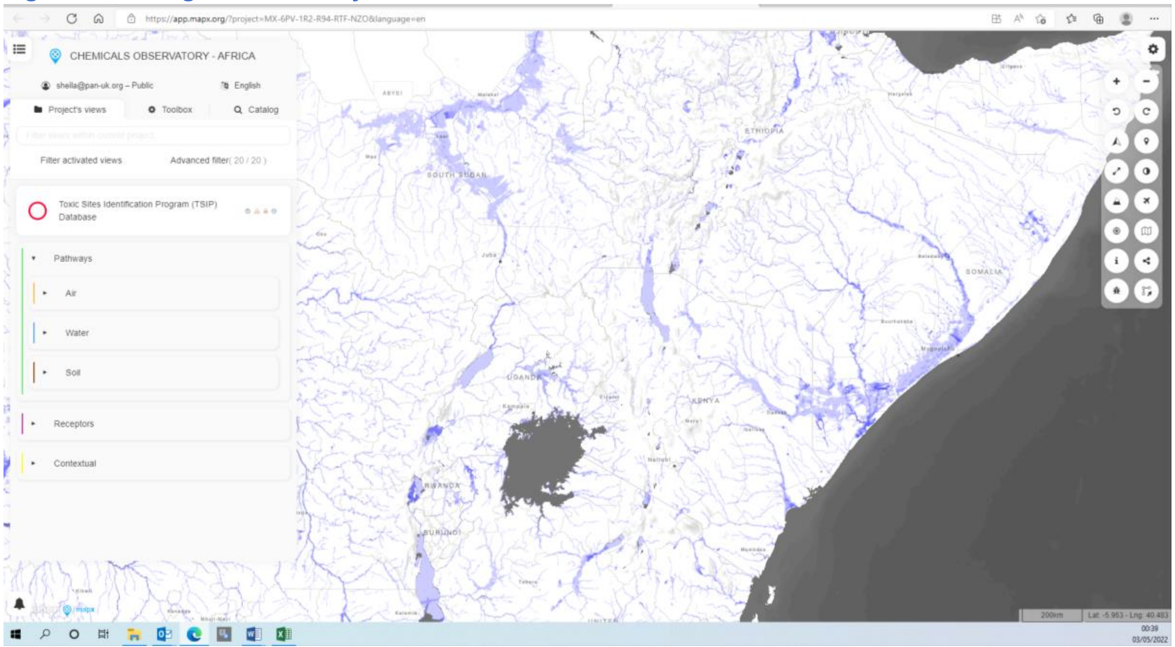
**Site Questions**

A minimum set of information is required from each site in order to run the calculator. An understanding of the volume and concentration of the chemical is needed either from labelled containers or sample analysis. This minimum information is compiled in a single **'Site Questions' sheet**, which can easily be distributed to project managers and other project staff, provided in Annex 6. The necessary information must be collected locally or drawn from grey literature from trusted sources e.g. university studies, government inventories. An important source in this case proved to be the Toxic Site Identification Program (TSIP) database developed by the US NGO, Pure Earth. The TSIP data is now integrated into the MAPX system and made available to end users.

**MAPX**

MapX is an open source web mapping platform developed by UN Environment, the World Bank and the Global Resource Information Database (GRID-Geneva) dedicated to data sharing, dissemination and visualization. The goal of MapX is to ensure that different stakeholders have access to the best available data to improve mapping, monitoring and decision-making processes related to the sustainable management of natural resources. For the purpose of the Risk and Vulnerability Calculator, MapX makes available a wide variety of geospatial data, including relevant indices such as land use, soil type and proximity to open water sources. The information is arranged in a similar order to the calculator with menu options for different pathways (air, water, soil) and demographic data under 'receptors'. This minimises the information needed directly from the site, but can be replaced if more accurate/recent data is locally available, giving local stakeholders more control of the process and a means to progress even when access to data is minimal.

*Fig. 4. Showing ChemObs Africa data in MAPX*




The panel on the left of Fig. 4 is arranged with pathway and receptor information ordered in a similar way to the calculator. In this example the map is showing information about areas prone to flooding in Kenya, which is selected from the water pathway menu on the left.

## *Outputs from the R&V calculator*

### *Scores*

The primary results from the R&V calculator are two scores, one concerning risk to human health and the other concerning risk to the environment. These are relative score with no units. They are used to compare one site with another in a very summarised way in order to support prioritisation. The scores could be used to compare individual sites or to compare one group of sites with another e.g. lead contaminated sites with pesticide contaminates sites or to compare sites in different geographical areas.

### *Comparison with benchmark site*

There are no threshold values in the calculator. However, to help compare site scores with a site that is considered relatively low risk, we have added a fictional 'benchmark' site in the calculator. The full information about this site is found in the 'Benchmark site' tab of the calculator. The benchmark site is a site with 5000l of each of two hazardous pesticides, DDT and Alachlor, stored in good condition in a sparsely populated area. The site scores relatively low for risk to human health and environment.

## *Red flags*

A calculation represents a compilation of a wide range of data concerning a particular site. In order to help with the interpretation, a 'red flag' feature has been added which highlights certain features of the sites which may be of particular importance. Of course, the end users does not need to be limited to this information if other features are of particular importance or interest.

*Figure 5 Table summarising 'red flag', 'people at risk' and hazard information*

| Red flags due to site conditions | | | | People at risk | | | Hazard (score 1-10 with 10 being the highest hazard level) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Poor / very poor container condition | Flood risk? | Prone to natural disasters? | High risk public building <100m | On site | <100m | 100-500m | Acute toxicity to mammals | High chronic toxicity to mammals?* | Toxicity aquatic organisms | Toxicity bees | Persistence |
| yes | - | - | - | 2 | 23 | 292 | 5 | TRUE | 5 | 1 | 1 |

* Chronic toxicity combines scores for cancer, mutagenicity and reprotoxicity. If any of these parameters scores 7 or more then the box will indicate 'True', a score of 6 or under for all three parameters reads 'False'

If the container condition is poor or very poor, then this will be flagged red to indicate that an important action to reduce risk at the site would be to repack the chemicals into safer containers. This should be done with caution, following relevant guidelines. If the site is prone to flooding or natural disasters then this will also be flagged red. Finally, we have provided a red flag where high risk public buildings are within 100m of the site. These include schools, hospitals, churches, markets, social venues and other sites where a large number of the public gather, particularly vulnerable people such as children and medical patients.

## *People at risk*

The calculator separates the human population into three groups; people working directly on the site; people living within 100m of the site perimeter; people living 100-500m from the site. Summary information on the number of people in these three groups is provided alongside the 'red flag' information in both the 'calculator' and 'summary results' tabs of the calculator. These groups are further disaggregated according to age and gender within the calculator.

## *Hazard data*

The full range of hazard information used in the calculator is provided in the data sheet of the calculator. At present, the calculator includes 16 industrial chemicals and 80 pesticides (provided in Annex 7) For the acute toxicity scores (for mammals, bees and aquatic organisms) scores of 7 or higher are flagged red. The chronic health effects score is drawn from the scores for carcinogenicity, mutagenicity and reprotoxicity. If any one of these scores 7 or higher then the box will indicate 'true' in red as shown.

## *How the R&V calculations were completed*

In order to use the calculator, national consultants were tasked with collecting data concerning sources of chemical pollution that met the minimum requirements to complete the basic 'site questions'. Consultants were advised to focus on data that was under five years old. If the chemical pollutants at these sites were not already available in the calculator data sheet, the consultant was asked to alert the PAN-UK team so that they could be added. Several of the national consultants struggled to access much data. The primary sources were the Pure Earth Toxic Sites Identification Programme (which has been linked to the MAPX system to make the data available to consultants and national teams), government inventories of pesticide stocks and Minimata assessments or artisanal mines.

National consultants were invited to collect any additional and relevant information that was available for the identified sites to use in the pathway and receptor questions. Where the information was lacking to complete the later questions, consultants were advised to access the information in the MAPX system. The consultants were then tasked with running the calculations in order to obtain the scores and they were asked to save their calculations for future reference.

## Resources

The following resources have been developed to assist use of the two calculators:

*Table 1. Resources developed to support the two calculators*

| Calculator | Resources | Date of latest version |
|---|---|---|
| R&V Calculator | Updated PAN R&V calculator (EN) | 29th March 2022 |
| | A note to project managers and decision makers concerning the purpose of the 'R&V Calculator' and the interpretation of results (FR/EN) | 29th March 2022 |
| | 'R&V Calculator' A user manual (FR/EN) | 16th March 2022 |
| | Video R&V scores (EN) | 16th March 2022 |
| | Video Using the summary results tab in the R&V calculator (ChemObs) (EN) | 16th March 2022 |
| | Video tutorial 'Completing the R&V Calculator Parts I & II (EN) | 29th March 2022 |
| Economic calculator | Updated Economic Calculator (FR/EN) | 1 May 2022 |
| | Updated Methods document (FR/EN) | 1 May 2022 |
| | Updated Step-by-Step (FR/EN) | 1 May 2022 |
| | Video Tutorial (3 videos) (EN) | 14 March 2022 |

Calculators and guidance available here: https://1drv.ms/u/s!AjyKoJoBZuIC0QDI-Q2wVsadVeeR?e=Boh5sq

## Country Level Reporting

Each of the countries involved in the project submitted reports to the Executing Agencies at different stages of the project which were in turn shared with the international consultants. These included a baseline report during the project preparation phase and progress reports submitted in 2020. Most countries submitted either economic or risk and vulnerability calculations. Six countries (Ethiopia, Kenya, Madagascar, Senegal, Zambia and Zimbabwe) submitted both. These reports were shared in various stages of completion with some of the more comprehensive submissions (e.g. Kenya, Senegal) including multiple sites presenting different contaminants in different regions. Other countries developed less rigorous submissions, including some having been completed with a single site example.

In addition to operational reports and completed calculators, a number of supplemental narrative reports were drafted and submitted by countries. There was some variation between these reports on theme and scope, though all related to chemicals and health in the target countries. Despite that variation, the net result of these submissions is a fairly comprehensive review of the thematic area.

*Table 2. Summary of the documents received and reviewed for this report, organized by project country.*

| | Baseline Report | Progress Report | Economic Calculator | R & V Calculator | Cost benefit | Data survey | Vulnerability | Policy and action plan | Theory of change | Guidedev | Additional reports |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ethiopia | ■ | | ▨ | ■ | ■ | ■ | ■ | ■ | ■ | | Prioritisation scoping; Situation assessment, Stakeholder mapping |
| Gabon | | ■ | | ■ | ■ | | ■ | | | | |
| Kenya | ■ | | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | |
| Madagascar | ■ | | | ■ | | | ■ | | | | |
| Mali | ■ | | | ■ | ■ | ■ | | ■ | | ■ | Monitoring and evaluation report |
| Senegal | ■ | | ■ | ■ | ■ | ■ | | | ■ | | |
| Tanzania | ■ | | ■ | | ■ | ■ | ■ | | ■ | ■ | |
| Zambia | ■ | ■ | ▨ | ▨ | | ■ | | | ■ | | |
| Zimbabwe | ■ | | ■ | ■ | | | | | | | Prioritisation mapping, Project proposal |
| Total | 8 | 2 | 6 | 4 | 6 | 6 | 4 | 3 | 5 | 3 | |

<u>Baseline Report</u> – General information on chemicals and health organized during the Project Preparation Grant Phase
<u>Progress Report</u> – Operational report on work conducted
<u>Economic Calculator</u> – Completed Excel document with site specific information entered
<u>R & V Calculator</u> – Completed Excel document with site specific information entered
<u>Cost benefit report</u> – Assessment of cost of inaction on chemicals pollution. Sometime relying on, other times referencing the Economic Calculator.
<u>Data survey</u> – Report of available environmental and health data identified by national consultants
<u>Vulnerability report</u> – assessment of a country's vulnerability to human health effects of chemical pollution
<u>Policy and action plan</u> – review of relevant national laws, regulations and programmes
<u>Theory of change report</u> – a narrative description of the current institutional context for the project and possible levers for precipitate action on chemicals and health
<u>Guidedev reports</u> – a review of existing national regulatory framework relating to chemicals management

The present report is restricted the use of risk and vulnerability and economic calculators only. Thus, while the other reports mentioned above provide important contextual information, they are not synthesized or assessed here. An exception is when these reports include information relating specifically to the use of the risk and vulnerability and economic calculators. A separate exception is when countries have opted to develop their own methods to reach the ends of the calculator, as Gabon has done for the cost of inaction. In both of these cases, the presented data are reviewed and summarized below.

# Results

## Results of Risk and Vulnerability Calculations

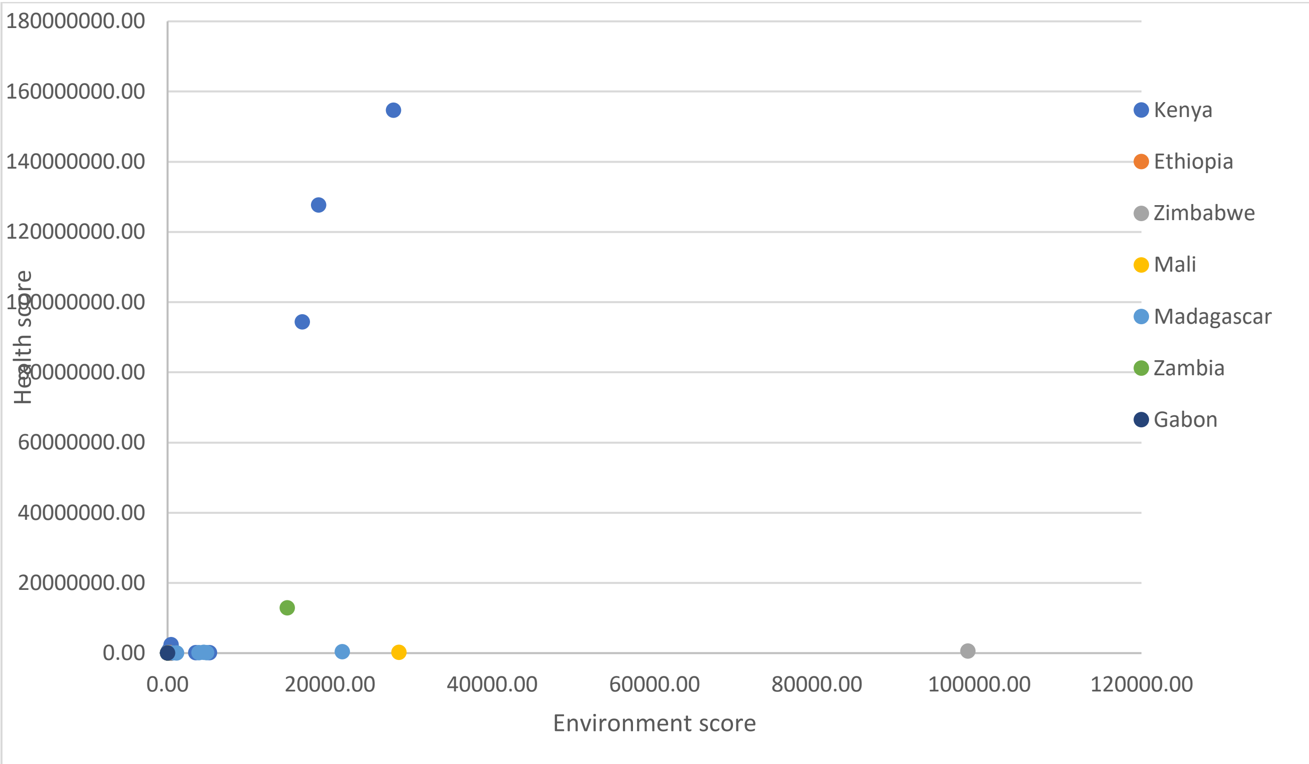
The results show that the number of sites and the type of chemicals for which data was available varied greatly from country to country. The final calculations can only reflect sites for which data was available of course and these may not represent the full range of chemical pollutants and sites in the country. More detailed results for each country are provided in annexes 8 - 15.

*Table 3. Summary results by country*

| Country | Data used in calculator | Key Findings and Recommendations |
|---|---|---|
| **Senegal** | 32 lead contaminated sites<br>9 pesticide stores / contaminated sites<br>33 mercury contaminated sites | Two sites identified with extremely high risk scores<br>Pesticide store (chlorpyrifos) belonging to DPV in Dakar<br>Group of garages (lead) in Dakar<br>Both lead and chlorpyrifos affect neurodevelopment and are disproportionately harmful to children. Both priority sites are located in highly populated areas<br>After these two sites, the next highest risk group of sites are garages contaminated with lead<br>Artisanal mines have been identified that are contaminated by mercury. The relatively low average score for the sites may mask very high risk for individuals working directly at the site Additional data concerning workers at the site and contamination of water and food would be advisable |
| **Madag-ascar** | 1 lead site<br>3 mercury sites<br>3 chromium sites<br>3 PCB sites<br>1 locust control area – pesticides in use | Work ongoing. Report should clarify findings and discuss recommendations. Additional resources have been provided to support data analysis and interpretation (March 2022).<br>Difficulties accessing quality data<br>Relatively high-risk site identified at Andralanitra (lead)<br>Ambalavato sud, Antsirabe and Ambohimanambola are priority sites for PCBs<br>Chlorpyrifos at several sites (pesticide used in locust control and for other crop pests)<br>Andralanitra reported lead, mercury, arsenic and chromium contamination |
| **Gabon** | 1 site of lead pollution<br>7 sites PCBs<br>4 sites pesticides in use<br>Manganese<br>Asbestos | Lack of data<br>A high priority site for PCBs at an equipment store identified in Libreville<br>Lack of data on lead. One contaminated site with relatively high risk identified at Mindoube<br>The pesticide sites were for pesticides in use and lower risk within the limited scale of the sites identified<br>Manganese and asbestos were not available in the calculator (asbestos has been added) |

| | | |
|---|---|---|
| **Mali** | A questionnaire was used to access data for<br>6 contaminated sites, pesticides | A site at Niono scored much higher for risk than other sites identified. Parathion (OP, class 1a), chlorpyrifos profenofos<br>Lack of data; recommendations made concerning improving data collection for chemicals and accessing such data as exists<br>Communications being prepared to raise awareness of risks with focus on gender<br>Lack of suitable storage for chemicals |
| **Ethiopia** | 35 DDT stores | 10 high priority sites identified, mainly health services stores<br>Issues identified include:<br>• Lack of monitoring and enforcement<br>• Lack of disposal facilities<br>• Lack of coordination on chemicals issues |
| **Kenya** | 32 sites contaminated with lead and mercury, DDT and PCBs | 3 sites emerged as very high risk in terms of exposure to lead poisoning. These sites included Kayole Informal ULAB Recycling Area, AP Lead Acid Battery Recycling Company and Dandora Municipal dumpsite<br>Despite having been decommissioned, the Kitengela Obsolete chemicals storage site had a high risk score, ranked fourth out of the 10 most polluted sites |
| **Tanzania** | Failure to access suitable data prevented the use of the calculator | The reports reference useful local studies on artisanal mining and mercury; sources of lead pollution, pesticides in foodstuffs including a useful review by Kwango in Dar on vegetable residues.<br>TSIP data is available but was not used in the calculations |
| **Zambia** | 2 DDT sites<br>2 lead sites<br>1 deltamethrin site | Calculations and interpretation missing from report<br>Kabwe lead mine was identified as a high risk scoring site<br>An interesting use of the calculator for indoor residual spraying of DDT<br>Additional material gathered e.g. on skin lightening creams, poisoning incidents, household pollution |
| **Zimbabwe** | 9 pesticide stores<br>1 site with pesticide-contaminated soil<br>Some assumptions were made due to missing details | Pesticide-contaminated sites were prioritised based on data from 2016, which showed sites with high contamination including with POPs<br>The results have been used to develop a proposal to update / validate the available data and safeguard obsolete pesticide stocks |

*Figure 6. Scattergraph of scores from R&V calculations from each country*

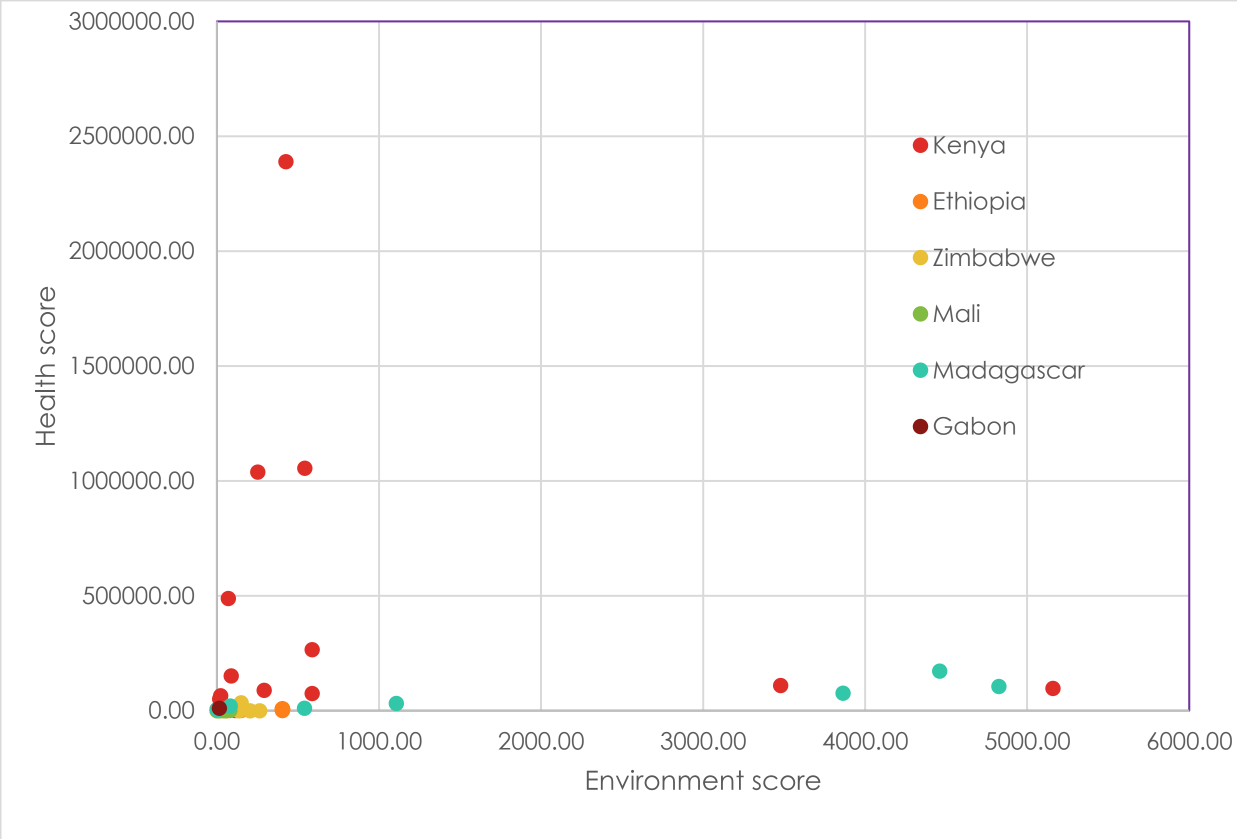



The graph shows that three sites in Kenya scored extraordinarily highly for risk to human health. These sites are Kayole Informal ULAB Recycling Area, AP Lead Acid Battery Recycling Company and Dandora Municipal dumpsite. They are all located in densely populated urban areas where there is open access and large numbers of waste pickers / workers. At Dondora, for example, estimates of numbers of waste pickers living and working on the site range from 3000 – 9000. The team used the higher end estimate in the calculations. More work is needed to determine a more accurate figure. There is a wider difficulty in sites such as open dump sites and artisanal mines that are open access, since the numbers living and working at the sites are rather fluid and difficult to obtain. Notwithstanding this caution over the numbers, there does appear to be a significant risk at large dumpsites in densely populated, urban areas with a highly vulnerable population living and working in and around some of these sites. Zambia has a very high scoring and extensive site at Kabwe mine, which is heavily contaminated with lead.

The site scoring highest for risk to environment was at Gwebi Agricultural College, where $m^2$ of soil is heavily contaminated with fenitrothion. Mali also had a very high scoring site at Niono which is contaminated with parathion, chlorpyrifos and profenofos while in Madagascar a site at Ambohibao contaminated with chlorpyrifos also scored highly.

If the seven highest scoring sites are removed from the graph, one has a better view of the spread of scores for the remaining sites.

*Figure 7. Scattergraph of scores from R&V calculations from each country with six highest scoring sites removed*

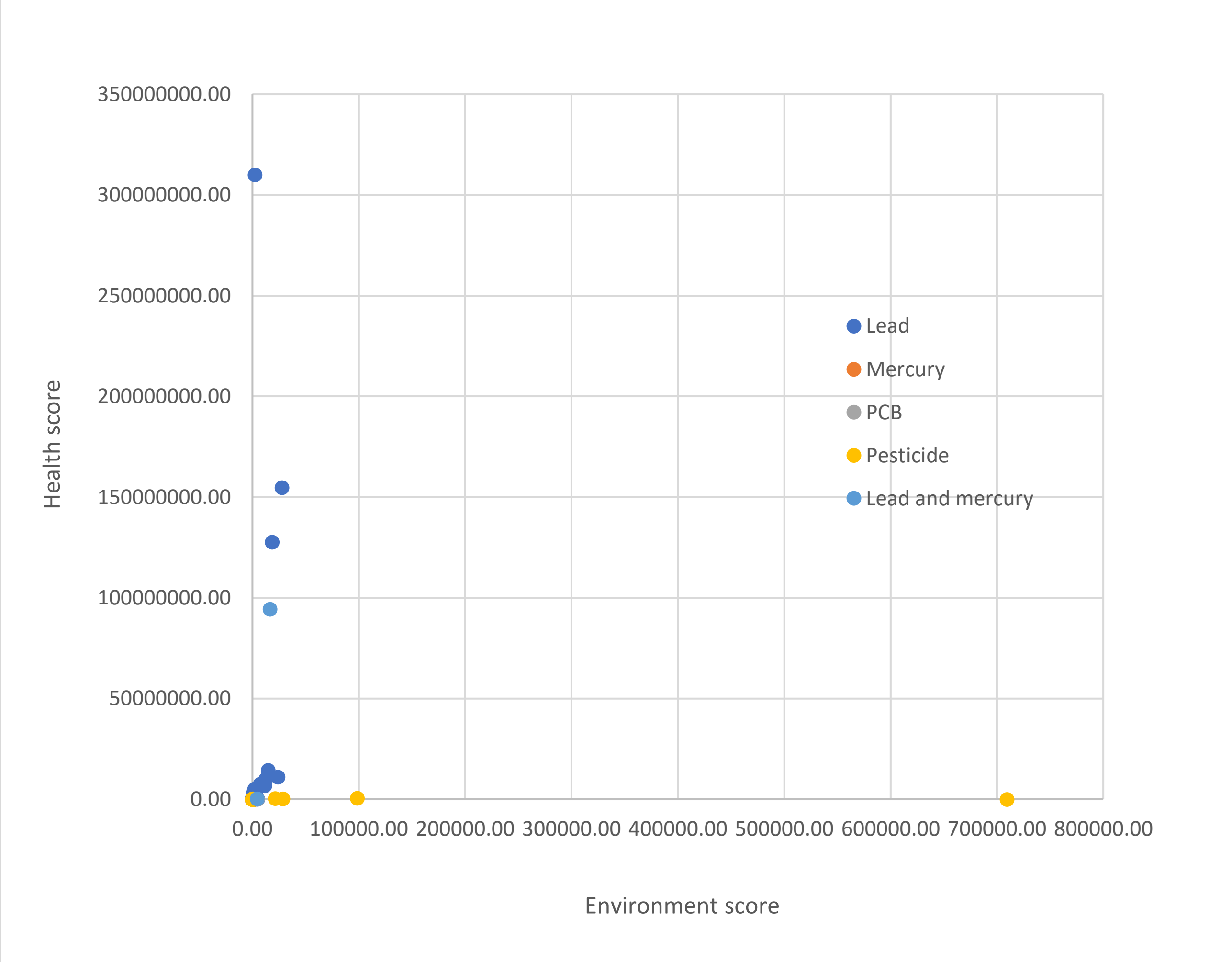



This graph shows that Kenya has many of the highest scoring sites, although this may be a function of the number of sites for which data was available for the calculations. Madagascar had several high scoring sites for risk to environment including two sites contaminated with PCBs (JIRAMA Ambohimanambola and Ambalavato sud Antsirabe) and one site contaminated with lead and mercury (Andralanitra). Madagascar is currently compiling new data and it would be interesting to see what it reveals in the calculations.

### *Comparing scores for different chemical pollutants*

Looking at scores across all sites for the different pollutants, the data we have indicates that many lead contaminated sites in particular pose a high risk to human health, while there are two pesticide-contaminated sites which score very highly for risk to the environment.

*Figure 8. Scattergraph comparing R&V scores for each type of chemical pollutant across all countries*



## Results of economic calculations

This section summarizes the results of the use of the economic calculator by country. In most cases a summary of the work conducted and the major results are presented. In the case of Gabon, an alternative approach is summarized. In the cases of Ethiopia and Mali insufficient data were shared with the international consultants to calculate productivity losses. Table XX presents a summary of the productive loss estimations by country and other general descriptive information.

*Table 4. Productivity loss estimations by country*

| | DALYs (USD) | IQ decrement (USD) | Total Exposed Population | Total Exposure Scenarios | Exposure Pathways Assessed |
|---|---|---|---|---|---|
| **Ethiopia** | -- | -- | -- | -- | -- |
| **Gabon** | 515,500 | -- | 150,000 | 3 | Soil |
| **Kenya** | 14,501,630 | 258,603,464 | 1,001,800 | 111 | Dietary, Dust, Soil, Water |
| **Madagascar** | 212,675 | 56,778,396 | 540,000 | 18 | Soil, Water |
| **Mali** | -- | -- | -- | -- | -- |
| **Senegal** | 177,000 | 43,000,000 | 24,600 | 84 | Soil |
| **Tanzania** | 21,246,040 | 0 | 992,700 | 90 | Dietary, Dust, Soil, Water |
| **Zambia** | 20,844 | 11,000,000 | 8,000 | 8 | Dietary, Soil |
| **Zimbabwe** | 13,474,294 | 120,091,020 | 1,970,600 | 99 | Dietary, Dust, Soil, Water |

### *Gabon*

At the request of Gabon, during the period covered by the report the international consultants developed a crude preliminary method for the calculation of productivity losses associated with Manganese soil exposure. The values presented by Gabon in their cost of inaction report are presented in that model in Table 5. No other chemical exposure data was presented by Gabon.

*Table 5. Preliminary values for productivity losses associated with Manganese exposure in Gabon.*

| Exposure scenario | Soil concentration | Per capita losses (USD) | Exposed population (Children 0-7 years) | Associated productivity losses |
|---|---|---|---|---|
| Low | < 10,000 mg/kg | 0 | 0 | |
| Moderate | 10,000 – 20,000 mg/kg | 2.50 | 0 | |
| High | > 20,000 mg/kg | 3.43 | 150,000 | **USD 515,500** |

### *Kenya*

Kenya completed and submitted one of the more comprehensive economic calculators in the project. The national consultants entered data across three major exposure pathways: soil, dietary and water. In total 111 different exposure scenarios comprising over a million people were entered. Contaminants assessed include aldrin, alpha and beta Hexachlorocyclohexane (HCH), chlorpyrifos, dieldrin, dimethoate, heptachlor, lead, malathion and p,p'-dichlorodiphenyltrichloroethane (DDT). The completed calculator represents a substantial effort to aggregate and standardize data collection in the country. These data were initially entered into the beta version of the calculator which contained multiple syntax errors and as such presented unrealistic and unreliable results. Importantly however, the Kenyan national consultants entered data meticulously and accurately. Thus when the syntax errors were repaired in the calculator, a revised estimation of productivity losses was easily calculated. The same data could continue to be used as updates are made to future versions of the calculator.

| | DALYs | IQ decrement |
|---|---|---|
| Dietary | 569 | 103,412 |
| Soil | 5,836 | 125,718 |
| Dust | 0 | 491 |
| Water | 40 | 9,261 |
| *Total* | **6,444** | **238,881** |

| | |
|---|---|
| Cost per DALY | 2,250 |
| Cost per IQ point | 1,083 |
| *Cost of DALYs (USD)* | 14,501,630 |
| *Cost of IQ decrement (USD)* | 258,603,464 |

Economic Inputs

Chemical exposures in Kenya were found to result in a total of 6,444 DALYs and 238,881 lost IQ points. These losses were valued at USD 12 million and USD 258 million respectively.

### *Madagascar*

Madagascar's completed economic calculator included two exposure pathways: water and soil. In total the completed calculator characterizes 18 different exposure scenarios comprised of 540,000 people. The consultants assessed three different chemicals: arsenic, lead and mercury. All data reported in Madagascar were taken exclusively from government reports. This is distinct from all other countries participating in the project which relied heavily on the peer-reviewed literature.

| | DALYs | IQ decrement |
|---|---|---|
| Dietary | 0 | 0 |
| Soil | 459 | 284,062 |
| Dust | 0 | 0 |
| Water | 0 | 0 |
| *Total* | **459** | **284,062** |

| | |
|---|---|
| Cost per DALY | 463 |
| Cost per IQ point | 200 |
| *Cost of DALYs (USD)* | 212,675 |
| *Cost of IQ decrement (USD)* | 56,778,396 |

Economic Inputs

### *Senegal*

Senegal completed one of the more comprehensive calculators as part of the project. Using data primarily collected by the US NGO Pure Earth, the consultant entered site specific soil contamination data for 84 different exposure scenarios comprising 24,600 people. include aldrin, chlordane, chlorpyrifos, dieldrin, dichlorvos, lead, mercury and p,p'-dichlorodiphenyltrichloroethane (DDT). No data were entered for either water or dietary exposure pathways. This was likely due to the near exclusive use of Pure Earth's dataset, which tends to focus on soil contamination. A more rigorous review might also consider the peer-reviewed literature and government sources.

| | DALYs | IQ decrement |
|---|---|---|
| Dietary | 0 | 0 |
| Soil | 107 | 37,173 |
| Dust | 0 | 0 |
| Water | 0 | 0 |
| *Total* | **108** | **37,173** |
| Cost per DALY | 1,651 | |
| Cost per IQ point | 1,173 | |
| *Cost of DALYs (USD)* | 177,518 | Economic Inputs |
| *Cost of IQ decrement (USD)* | 43,617,444 | |

In total the chemical exposures assessed by the calculator in Senegal amounted to USD 43 million in productivity losses from IQ decrement and USD 177 thousand in losses attributable to DALYs.

### *Tanzania*

Tanzania's completed economic calculator included three exposure pathways: dietary, water and soil. In total the completed calculator characterizes 90 different exposure scenarios comprised of 992,000 people. Assessed contaminants include aldrin, alpha and beta Hexachlorocyclohexane (HCH), dieldrin, heptachlor epoxide, lead, mercury, and p,p'-Dichlorodiphenyl dichloroethane (DDD). Importantly, Tanzania's calculator characterizes adult exposures only. Children (0-7 years) have not been considered in any of the exposure scenarios. Thus productivity losses are calculated for carcinogens and heart disease attributable DALYs only. If the calculator were expanded to also include entries for children the total cost would be substantially larger than the present estimate.

| | DALYs | IQ decrement |
|---|---|---|
| Dietary | 5 | 0 |
| Soil | 18,297 | 0 |
| Dust | 0 | 0 |
| Water | 1 | 0 |
| *Total* | **18,303** | **0** |
| Cost per DALY | 1,161 | |
| Cost per IQ point | 562 | |
| *Cost of DALYs (USD)* | 21,246,040 | Economic Inputs |
| *Cost of IQ decrement (USD)* | 0 | |

### *Zambia*

Zambia's economic calculator included two exposure pathways at a single site, the Chowa neighbourhood of the city of Kabwe. Lead contamination resulting from a mining-smelting complex has been well characterized in the city of Kabwe, which has been the subject of multiple peer reviewed journal articles and two World Bank supported projects to mitigate the contamination. If the calculator were expanded beyond this single neighbourhood, the total cost would be substantially larger than the present estimate. The current version of the Zambia calculator includes 8 exposure scenarios comprised of 8,000 people that include both adults and children. The total cost in DALYs for community was estimated at USD 20,844 and in IQ points as USD 11 million.

### *Zimbabwe*

The consultants from Zimbabwe completed one of the more comprehensive calculators received by the international consultants. The calculator utilizes all four available pathways and considers 99 exposure scenarios comprised of nearly 2 million people. Both adults and children were considered as were a range of contaminants, including arsenic, dimethoate, lead, mercury, and p,p'-Dichlorodiphenyltrichloroethane (DDT). In nearly all cases the source of data was cited, allowing entries to be independently confirmed. Several of the initial population estimates exceeded realistic scenarios and were scaled back to more conservative estimates. The total costs of chemicals exposures in Zimbabwe were estimated to be USD 13 million form disability adjusted life years and USD 120 million from IQ point decrement.

| | DALYs | IQ decrement |
|---|---|---|
| Dietary | 166 | 155,573 |
| Soil | 132 | 97,304 |
| Dust | 1 | 972 |
| Water | 11,611 | 52,198 |
| *Total* | **11,910** | **306,046** |
| Cost per DALY | 1,131 | |
| Cost per IQ point | 392 | |
| *Cost of DALYs (USD)* | 13,474,294 | Economic Inputs |
| *Cost of IQ decrement (USD)* | 120,091,020 | |

# Lessons Learned

## Data availability and access

With regard to environmental monitoring data, the existent data varied substantially in geographic and chemical scope. In general reasonably recent and comprehensive government data on effluent and point source air emissions were available on large industrial installations in most countries. Municipal drinking water in large cities was also reasonably well monitored. By contrast data on informal industry or contaminated sites tended to be more ad hoc having been collected by academics, NGOs or UN agencies. TSIP data, POPS assessments and mercury assessments under Minamata were useful sources of data for the R&V calculations.

With regard to availability, environmental data held by government agencies could almost universally not be accessed. In some cases this was due to logistical challenges. Data were rarely networked; information tended to be stored on single computers as either Excel spreadsheets or, more commonly, as PDFs, Word documents, or similar. In many cases, only hard (i.e. paper) versions of results were available. Administrative challenges also existed. Procedures to access were unclear and there was limited willingness at the agency level to make data available. By contrast, data from academics, NGOs, and UN Agencies was generally readily available.

With regard to health monitoring data, in general data does seem to exist in each country. These data are typically stored in a regularly updated health information system (HIS) database that is regularly updated. However, data on incidents of poisoning recorded by the HIS system is seemingly very limited Like government environmental monitoring data, these data were not readily available to international consultants. Annex 1reports on the results of country visits carried out by the consultants.

Mercury use in artisanal mines is a concern in several countries and the calculator has been used with soil data from these sites. Of course, it can be extremely locally concentrated and average levels over a site may mask significant variation and fail to take sufficient account of the extreme risk of individuals directly handling the mercury at the site. Landfill sites for mixed waste are important source of pollution but difficult to assess with this method due to wide variety of pollutants and variability in time and space. It can be difficult to get accurate estimates of people working directly at both these types of sites since they are informal workplaces and open access. Numbers can be rather fluid.

## Technical limitations

At present the R&V calculator does not include risk of fire or flammability of the materials.

The pathway data is fairly laborious to collect from MAPX. The hope is that this will be automated in future, making the calculator much quicker to complete

Interactions between chemical pollutants can increase risk. It would be technically straightforward to adjust the calculations scores according to different pollutants present but their interactions are complex and poorly understood, so it was felt that this was beyond the scope of the current exercise

## National capacity to complete calculations

Eight of the nine countries completed either a Risk and Vulnerability or Economic Calculator as part of the project. Of these, six managed to complete both. There was substantial variation between the quality and comprehensiveness of the submitted data. In the more successful cases a large amount of site data was entered correctly allowing for subsequent calculations. In the less successful cases more limited site data was entered and often in the wrong format. In general the barriers to completing robust calculations were more closely related to data access or operational considerations than to technical challenges. Data access issues are described above.

Operational challenges included a lack of synchronisation between national and international consultant contracts over the 5-year project time frame and multiple challenges of operating during the COVID-19 pandemic. Of note, field trials for both calculators were mostly carried out in 2020. This lack of synchronisation resulted in the occasional absence of technical support for national consultants and – perhaps most significantly – substantial delays in correcting syntax issues with the economic calculator.

Technical challenges encountered by the national consultants were relatively small in number. To some extent this confirms that the calculators and associated guidance are organized in a logical and intuitive manner. It was also likely due in part to the overlapping 'belt and suspenders' approach to project implementation. Specifically, the project developed multiple guidance documents and instructional videos to facilitate independent learning of the tools. These were supported by in person and online trainings as well as through pre-recorded video instruction. Finally, the ChemObs tools were integrated into a certificate course at the University of Cape Town in which several country representatives and national consultants were enrolled.

The lack of technical challenges can also be attributed to the high capacity of the national consultants engaged. In general, the consultants possessed a professional level of knowledge on issues of chemicals and human health and maintained robust networks.

# Conclusions

The results of the project varied substantially across the targeted countries. In the least successful cases, adequate data could not be identified or accessed by national consultants resulting in incomplete or nonexistent calculations.  In the more successful cases, a large amount of data on multiple chemical exposures sources were identified, accessed and organized. In these cases different exposure pathways were considered. Reasonable estimates of costs of inaction were developed and sites were evaluated for their relative risk to the human health and the environment. The calculators were then revised in an iterative process and refined based on user feedback. The result is a set of calculators that could be readily employed in future projects. They have been externally reviewed and received broadly positive endorsement.

All data collection and calculations were completed by national consultants or country representatives. This is distinct from previous similar efforts which have often relied more heavily on international consultants.

A significant challenge for many of the countries was accessing suitable data, as described in the previous section. While many studies of chemical pollution have been done by various institutions in most of the countries, it is not collected or listed centrally in any of them and data is rarely networked or stored in a format that could be easily collated. Administrative challenges also existed between different ministries and institutions. By contrast, data from academics, NGOs, and UN Agencies was generally readily available. This, perhaps, points to the value of having an institutional role for bringing such data together, which would offer opportunities to better identify and address gaps as well as ensuring consistent and compatible methodology so that such resources as there can be better used. Access to data in the MAPX system proved to be a very valuable resource for the R&V calculations and, beyond that, it would be valuable for project managers and planners working as well as policy makers..

It is worth noting that the results of the calculations at the national level reflect some of the challenges encountered by the international consultants during country visits. Specifically, the calculations in the economic calculator universally rely on peer-reviewed studies rather than government monitoring data. It is likely that this reflects challenges related to availability rather than the existence of data. The R&V calculations are also limited to sites where the minimum data is made available. In Ethiopia, for example, calculations were limited to government DDT stores but other types of chemical pollutants do exist in the country.

The R&V calculations identified a widespread and significant risk to human health from lead pollution in particular. The problem of waste dumps and recycling facilities with high levels of lead contamination, often located in densely populated areas with open access, represent a particular problem across multiple locations. Some heavily contaminated sites with pesticides also scored very highly. These latter sites are often government-owned pesticide stores.

The R&V calculator was tested on data for pesticides in use and indoor residual spraying. This rather innovative use of such a tool seems to be worthy of further testing and development.

# Annex 1. Summary results of data assessments in participating countries

*Data assessment was not undertaken by the international consultants in Ethiopia and Madagascar

| Type or source of data | Kenya | Tanzania | Zambia | Zimbabwe | Ethiopia | Gabon | Madag-ascar | Mali | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| HIS | > 85 % capture of cases presenting at medical services | Exists<br>% capture unknown | Exists, extent unknown | > 90 % coverage | | Exists<br>diseases registered in health structures across the country | | Exists<br>diseases registered in health structures across the country | Exists<br>Diseases registered in health structures across the country |
| Ambient Air Quality Monitoring | 1 regular ambient air monitor (Nairobi). AP monitoring done as part of GMP | Limited air monitoring as part of GMP but no data in the GMP data warehouse - recetox | 2 regular ambient air monitors (Lusaka and Copperbelt). AP monitoring done as part of GMP | None | | None.<br>Pilot project with Oregon University | | None. AP monitoring done as part of GMP and MONET Africa at Sotuba | Regular ambient air monitor at Dakar. AP monitoring done as part of GMP (at Ngoye) |
| Point source air monitoring | Unknown | None | Unknown | Quarterly monitoring of 2000 sources. Stored in Excel | | None | | None | None |

| Type or source of data | Kenya | Tanzania | Zambia | Zimbabwe | Ethiopia | Gabon | Madag-ascar | Mali | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| Surface and groundwater monitoring | Regular, comprehensive monitoring of major rivers by WARMA. NEMA take the lead on effluent monitoring. | Water testing is funding-dependent, data difficult to access and not digitised | Unknown | Monthly monitoring of 364 points nationally. Stored in Excel. | | Monitor major rivers and ground water by Directorate of water resources | | Monitoring of major rivers and groud water | Monitoring of major rivers and groud water (DGPRE) |
| Drinking water monitoring | Unknown | See above | Done by private providers. Chemicals analysis in Copperbelt only. | < Semiannual sampling of municipal water supplies annually. 2000 samples total stored in hard copy | | Done by private providers | | Laboratoire national des eaux | Done by private providers |
| Other chemicals imports | Unknown | Types Quantities tbc Held by GCLA | Unknown | Types and quantities | | Unknown | | Unknown | Unknown |
| Pesticide register | Yes | Yes HHPs being identified | unknown | unknown | | Unknown | | unknown | Unknown |
| Pesticides imports and exports and domestic | Types and Quantities import and export data held by PCPB database. | Types and quantities held in digitized form (tbc). Apparently no pesticides are exported. | Types | Types and quantities | | Unknown | | Types and quantities held by National Directorate of Agricultue (tbc). | Types and Quantities import held by DPV. Export data held by SPIA (pesticide |

| Type or source of data | Kenya | Tanzania | Zambia | Zimbabwe | Ethiopia | Gabon | Madag-ascar | Mali | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| production / formulation | Empty container problem. | TPRI test pesticide quality, issue import licenses and hold data. | | | | | | No pesticides formulation in the country. Empty container problem | company). Empty container problem . |
| Farming systems (distribution of crops and large vs small farms) | Unknown Approx. 40 pesticides distribution companies | Unknown | Exists, extent unknown | Unknown | | Exists, extent unknown | | Exists, extent unknown | Exists, extent unknown |
| Pesticides residue in food | Exports assessed by parastatal lab KEPHIS. Domestic food not assessed | TFDA conduct routine residue analysis for export crops. GCLA conduct analysis for disputes / verification. | Not assessed | Not assessed | | Labs exists. Lack resources. No systematic analysis | | Central veterinary laboratory (GMP lab) routine residue analysis. No systematic. | Ceres Locustox (GMP Lab) conduct some residue analysis in vegetables, water, soils. .. |

| Type or source of data | Kenya | Tanzania | Zambia | Zimbabwe | Ethiopia | Gabon | Madag-ascar | Mali | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| Toxic Sites Identification Program | 126 sites | 170+ sites | 2 sites | 17 sites | | None | | Unknown | 21 sites identified by Pure Earth |
| Monitoring industrial facilities | Environmental audits online. 2000 facilities checked for effluent water quality. New regulations in draft. Inventorising industrial chemicals and enterprises has started in 4 counties. | EIAs hard copy only. A limited database at NEMC lists locations and sector of facilities that have an EIA. | Unknown | Unknown | | None | | Unknown | Environmental audits and control by DEEC. |
| Global Monitoring Program | Yes Conducted by the University of Nairobi | Yes. See air quality monitoring | Yes | No | | None | | Yes. Conducted by CVL and Health directorate coordinated by DNACPN | Yes Conducted by Ceres Locustox and Poison Center coordinated by DEEC |
| Waste (all types) | Significant problem all kinds of waste | Very significant problem | | | | Significant problem all kinds of waste | | Significant problem all kinds of waste | Significant problem all kinds of waste |

| Type or source of data | Kenya | Tanzania | Zambia | Zimbabwe | Ethiopia | Gabon | Madag-ascar | Mali | Senegal |
|---|---|---|---|---|---|---|---|---|---|
| | and concern regarding incineration facilities.<br>Data unknown. | Individual studies show high levels of contamination at recycling facilities in urban areas | | | | and concern regarding incineration facilities.<br>Data unknown. | | and concern regarding incineration facilities.<br>Data unknown. | and concern regarding incineration facilities.<br>Data unknown. |
| Baselines assessment for Minamata | Unknown | Yes | Unknown | Completed by consultant. Submitted to Africa Institute | | Yes in progress | | Yes in progress | Yes.Done |
| Demographic and social data | Yes<br>A new census by KNBS due 2019 (last one 2009)<br>See also Kenya Demographic and Health Survey 2014 http://statistics.knbs.or.ke/nada/index.php/catalog/74 | Yes<br>National household surveys conducted by NBS. Data available online. | Unknown | Unknown | | Yes. Some data available online with General Directorate of Statistics | | Yes. No specific data on chemicals.National household surveys conducted by National Institute of Statistics.Some data available online. | Yes. Statistics relevant for regional level in the country By National Agency for Statistics and Demography |

# Annex 2 Peer Review of Economic Calculator

## Terms of Reference Peer review of ChemObs risk calculators and associated guidance

### Objectives

The ultimate objective of this Terms of Reference is the peer-review of the economic and vulnerability calculators developed as part of the project 'Integrated Health and Environment Observatories and Legal and Institutional Strengthening for the Sound Management of Chemicals in Africa (African ChemObs)' (GEF ID 9080). The specific services required are described below in 'Provision of Services Required.'

### Background

The overall objective of the African ChemObs Project is to contribute to improved health and environment protection through strengthening national and regional institutions, developing country owned plans of action and implementing priority chemicals and waste related interventions. The project seeks to develop a prototype of a national integrated health and environment observatory, including a core set of indicators enabling data aggregation, to provide timely and evidence-based information to predict, prevent and reduce chemicals risk to human health and the environment. More specifically, it addresses the necessary improvements to be made in the fields of awareness, knowledge, information management and communication on chemicals to support and provide an enabling framework for measures and actions to be taken.

Its implementation by project countries will contribute to improving capacity for data collection throughout the life cycle of chemicals; establishing an integrated health and environmental monitoring and surveillance system; reducing risks posed by chemicals and raising community awareness; a formal mechanism for intersectional coordination for health and environment; and improved understanding of the link between health and environment issues, to facilitate effective policymaking.

This project proposes to support the development of national observatories, capacity building of staff, support to identify causal pathways, risk ranking and priority settings, and activities to break links in causal pathways, thereby improving health and environment outcomes. The project has three components, which consist of the activities indicated below. Each component includes information on project activities, outcomes and outputs.

#### *Component 1*

Is focused on strengthening capacity of selected existing relevant national government departments and institutions to monitor pollution, prioritize areas for intervention as well as plan and implement solutions through active involvement of local communities.

#### *Component 2*

Is focused on the development of broad-based action plans to promote sound chemicals management and reduce negative impacts on health and the environment.

#### *Component 3*

This component will focus on the support for the sound management of chemicals in African countries to reduce risks from chemicals and wastes identified as posing specific risks to public health and environment.

Major headways were achieved on enhancing and strengthening institutional capacities for chemicals control and in term of risk and economic calculations. First Chemical Risk and Vulnerability Calculator coupled with economic valuation calculator have been developed to offer new tools to support national authorities towards a better estimation of the chemical risks prioritizing actions to be taken and estimation of the costs of certain chemicals on human health and the environment and support evidence-based decisions in chemicals management. The Chemical Risk and Vulnerability Calculator is designed to provide a relative risk assessment of different chemical pollutants, from point source (e.g. stores and contaminated sites) through pathway (water, soil, air, workplace) to receptors (population on site, public facility etc..). They are being tested and applied in nine African countries (Ethiopia, Gabon, Kenya, Madagascar, Mali, Senegal, Tanzania, Zambia, Zimbabwe).

A prototype version of the ChemObs portal has been developed by UNEP MapX to help communicate the impact of interventions in a visually compelling way based on dynamic maps and dashboards.

These outcomes aim at providing an information and data management system that is making the best use of existing information while breaking new ground in combining available information in the most innovative and scientifically reliable manner. These Tools and methodologies will support UN Country teams and the countries to link environmental and chemicals management aspects into social and economic dimensions of SDGs. With the full integrated guidance being delivered, their testing in countries and first business cases for investment to prevent and reduce chemicals risks are now expected to be delivered in 2021.

### *Institutional Arrangement and Project delivery Process*

The World Health Organization and Africa Institute serve as executing agencies for the implementation of the Africa ChemObs project in Ethiopia, Gabon, Kenya, Madagascar, Mali, Senegal, Tanzania, Zambia and Zimbabwe.

## *Provision of Services Required*

### *General Requirements*

Pesticides Action Network, United Kingdom (PAN-UK) seeks a consultant to peer-review the Economic Calculator and associated guidance developed as part of the UNEP implemented project 'Integrated Health and Environment Observatories and Legal and Institutional Strengthening for the Sound Management of Chemicals in Africa (African ChemObs)' (GEF ID 9080). The consultant should have extensive relevant technical expertise.

### *Specific Deliverables and Proposed Timeline*

The consultant will be responsible for delivering the following outputs by 1 December 2021.

- Consolidated comments (General and specific) on the economic calculator and associated guidance documents;

### *Remuneration*

The contract includes two lump sum payments of equivalent amounts totalling USD 5,000. The first payment will be made upon signature. The second will be made upon acceptance of all deliverables.

| Milestone | Payment |
|---|---|
| Signature of agreement with PAN-UK | USD 2,500 |
| Acceptance of all deliverables by PAN-UK | USD 2,500 |
| **Total** | **USD 5,000** |

### *Evaluation Criteria*

### *Summary*

Potential consultants will be evaluated against a short list of criteria provided below. These include minimum qualifications and 'additional criteria,' which will be evaluated on a relative basis.

Required minimum qualifications:

- Relevant PhD, DrPH, MD or equivalent;
- Experience working in low- and middle-income country context (minimum 10 years);
- Track record of published original research (minimum 5 publications);
- Experience as a peer-reviewer (minimum 5 years);
- Ability to provide 3 references. Additional evaluation criteria
- Experience with burden of disease calculations (# years);
- Experience with burden of disease valuations (# years);
- Experience working on contaminated land issues (# years);
- Experience with GEF projects or UN organizations (# projects).

## Review comments on the ChemObs environmental health economic calculator

December 10, 2021

We have with great interest followed the development of the environmental health economic calculator which is one of the outputs of the ChemObs Africa project. As the health costs associated with environmental pollution commonly are not fully recognized, we welcome the intention of the ChemObs project to develop tools that can estimate the magnitude of these costs in order for them to be taken into account in decision-making processes.

In accordance with the contract between PAN UK and Daniel Slunge (November 16, 2021) we hereby provide our comments and suggestions on the Environmental health economic calculator developed as part of the project "Integrated Health and Environment Observatories for the Sound Management of Chemicals and Waste in Africa" (GEF ID 9080), "ChemObs". These comments have been written by Dr. Daniel Slunge, Sweden and Dr. Richard Mulwa, Kenya. Both reviewers are active researchers within the Environment for Development Initiative (www.efdinitiative.org).

Our comments are based on a review of the excel-based "Calculator for the estimation of adverse health outcomes and associated productivity losses resulting from chemicals exposure" (Nov. 16) and the accompanying word files "Methods for Underlying Calculations " (Nov. 16) and "Step-bystep Guidance" (Nov.16). Besides reading the documents we have also tested the excel calculator by imputing different numbers

In this report, we first address some issues relating to the intended use of calculator and then proceed with comments on the content of the calculator and supporting documents as well as on the interpretation of the generated results. We also provide some detailed comments on the three documents reviewed.

## *General comments*

1. Comments on the purpose and the intended use of the calculator

Elaborate on who will use the calculator and when the calculator may be used: The step-by-step guidance takes the user of the calculator through five steps. However, we think there is a need to clarify a few more basic things either in the introduction to the calculator or in an accompanying document: Who will use the calculator? In which situations? For which purposes? Without a clear purpose and knowledge about the intended user and use-situations it is difficult to assess the appropriateness of the current design.

Add further guidance on how to use the calculator. The current methods and step-by step documents are rather technically oriented. We think this information need to be complemented by a text on the background, different potential uses of the calculator, what to think of when collecting and using input data and, not least, how to interpret and communicate the results generated. Some information on communication and uncertainty is included in an appendix, but we fear that this may be too complicated for the intended users.

Focus on estimating cost of inaction for specific problems rather than country wide assessments of multiple pollutants: We strongly suggest that the calculator should primarily be used to estimate cost of inaction related to specific problems, such as lead polluted sites in a certain region, or effects of pesticide polluted diets by children in a certain city. Given the many assumptions in combination with low quality input data, makes the adding up of multiple estimates of multiple pollutants less 2 useful, as estimates become very uncertain. This is in line with the statement (which we endorse) "The model is not intended to produce a definitive calculation of health and economic outcomes, but rather an indicative estimate based on the best available information. Future efforts might consider refining and improving the methods presented here. Given the paucity of efforts in this area, the model is intended as a 'proof of concept' of a tool that – following further improvement, review and testing – could be used in addressing a significant and credible health risk."

Pilot testing of the calculator. As the calculator is a novel tool, we strongly recommend that the launching of the calculator takes place in phases. This would include one or several pilots, trainings for those using the calculator, evaluation and learning, before the use of the calculator is scaled up for use in all of the ChemObs countries. The over estimations reported from the early testing of the calculator supports the need for a process oriented approach.

Make sure the calculator can be easily updated and revised: As the calculator is produced by external consultants it is important that there is also clear guidance on how to update and revise the calculator. The input data will need not only to be updated, but also revised based on lessons learned from applying the calculator. We suggest that a specific guidance on how to update and revise the calculator be developed including a clear description of the data-sources used, also for the sheets "hidden" in the calculator.

2. Comments on the content of the calculator and the supporting documents

Merge the methods and the step-by step guidance? Both the methods and the step by step document include an identical section "Inputs" explaining the sheets in the calculator. Also the section "Determining the size of the exposed population and frequency of exposure" is identical in the two documentsWe think these short documents would benefit from being merged and expanded with some further background and advice into a more thorough guidance document.

Add some explanatory information to the excel calculator. Also the excel calculator would benefit from some additional information and clarifications to assist the user. Some suggestions for such additions and clarifications are included in the detailed comments below.

The quality of input data needs to be explicitly discussed. The quality of the output of the health economic calculator of course depends on the quality of the input data. However, a well-known problem regarding environmental pollution, not least in African countries, is the lack of good data. There is currently no quality criteria for studies and data used as input to the calculator. The calculator would clearly benefit from adding a discussion of what type of studies and data may be used as an input to the calculator. Also, the studies used should be clearly cited so that the user of the calculator, or a reviewer of the results, has the possibility to assess the quality of the data.

The size and age of the exposed population: Besides the concentration of the pollutants in the different environmental media, the person running the calculator is also expected to add information about the size and age of the exposed population. As rightly pointed out, this introduces a large amount of uncertainty to the estimates. One way to address this could be to include a possibility to give a lower and a higher bound estimate. Currently there is a possibility to choose if the population is “child 0-7 years” or “adult >15 years”. The age group 8-15 years is missing. Why? Also, it would be desirable to further specify the Adult category as we know that disease outcomes can be highly correlated with age.

Modelling assumptions: The modelling assumptions for moving from the input data on environmental pollution to estimated DALYs and IQ loss are succinctly described in the methods document. As economists, it is beyond our area of competence to scrutinize the validity of the assumptions used. As we think that many of those using the calculator will have difficulties in understanding and assessing these assumptions, we suggest that some further information on the assumptions used is included. For example, in the description of the assumptions used in relation to Carcinogens (including the organochlorine pesticides) on page 5 it is stated that “the use of 50 % is intended to be conservative…”. Similar remarks on the implications” of the different assumptions would be useful in order for the user to know if estimates are likely to be on the lower or upper end etc. For example, how should the user or decision maker interpret the bold assumption of “a uniform impact of all OP pesticides on brain development”, based on values from the commonly used pesticide dimethoate.

The model is static rather than dynamic: While the assumptions made in the model are many and sometimes sophisticated, it is important to underline the static nature of the model. By for example assuming a uniform exposure to a population of a specific pollutant (mean value) the model fails to take into account the effect of protective behaviour which may greatly reduce exposure and cost of inaction. On the other hand, if it is peak exposure, not mean exposure, causing most harm, the calculator may underestimate the cost of inaction.

Need for region specific data on values of DALY and IQ loss. Ideally there would be African data underpinning the calculation of disability weights as well as productivity losses. More data collection and analysis will be required to create a more representative analysis.

Is there an urban bias? There is a special paucity of good data in rural areas in African countries why the application and interpretation in these areas should come with special caveats concerning the quality of input data

3. Comments on the presentation of modelling results.

Present data sources, summary graphs, sensitivity tests and benchmarks: Given the large uncertainties involved in estimating the health economic costs from environmental pollution it is crucial that the results are presented in a sensible way. The calculator would benefit from including the following elements in a results presentation:

- A clear description of the data sources on pollution, including references to relevant studies
- A summary (perhaps a flowchart?) of how the modelling was conducted.
- Illustrative diagrams of key results – templates could be created in additional excel sheets in the calculator
- A sensitivity test so it is clear to the reader what drives the results. "Tornado diagrams" could be used to illustrate a simple one-way sensitivity test.

It could also be useful to include some benchmark values from previous studies on the economic costs of different forms of pollution. This would help both the analyst and the decision makers to understand if the presented figure represents a very high cost or not.

Facilitate the presentation of monetary estimates alongside damages in physical terms. The Appendix "Primer on Costs of Action/Inaction and Communication to Policymakers" states that "In 4 communicating pollution damages in a cost-of-inaction study, or benefits (i.e., reduced damages) in a CBA, damages (or benefits) should first be described in physical terms. This might include morbidity, mortality, impacts on IQ, or other impacts. It is useful to present physical impacts (when appropriate) by age, gender, and the geographic region in which they occur." We endorse this and suggest that either (i) the excel calculator be complemented by additional sheets where the physical damages are more clearly presented, or (ii) the guidance document accompanying the calculator be expanded with advice and examples on how the physical data can be presented alongside the monetary estimates.

Elaborate on how to communicate uncertainties and limitations associated with the data. The Primer on Cost of Inaction states that "when valuing these impacts, it may be prudent to present both conservative estimates of damages—e.g., estimates of the costs of illness associated with morbidity and earnings losses associated with premature mortality—as well as what economists call welfare benefits…". We note that other calculators (for example the Burden of disease toolkit of the European Centre for Disease Control, https://www.ecdc.europa.eu/en/publications-data/toolkitapplication-calculate-dalys) allow for parameter uncertainty by including both mean values and confidence intervals from the input data. This limitation of the current version of the health economic calculator should be explicitly recognised.

## *Detailed comments*

Excel calculator

- The name of the country for which the calculation is being made should be clearly stated on each sheet of the calculator
- Include a weblink to the associated guidance documents on each sheet of the calculator.
- It would also be user friendly to have a short instruction on each sheet. For example, on the sheet "Economic Inputs" it says "If country specifc data are available they can be entered here", but further information is needed to explain where to get this data. It would also be useful to include a short explanation telling the user that "Data for "Country" has been inputed from source x,y z"
- Dietary sheet:

  - Food: The information needed here is clear and straight forward, but we recommend the scientific name be included. For the calculator to be more user friendly, the list can be made available in the calculator.
  - Weight ingested daily (kilos): Not really clear how the user should go about this? Maybe the calculator can recommend sources of information and provide links. There are different sources of dietary guidelines, with some more region specific such as the dietary guidance for Americas (https://www.hhs.gov/fitness/eathealthy/dietary-guidelines-for-americans/index.html). Another is http://www.fao.org/nutrition/education/food-dietary-guidelines/home/en/.

<u>Step-by-Step Guidance</u>

- Reference is repeatedly made to the "Population guidance" for assistance. We could not find this guidance in the documentation. Please clarify.

<u>Methods document</u>

- Small errors in the example sheets on page 3. For dietary it says "exposed to soil", should be food (same for Water); The chemical exemplifies in the Dust and soil sheets is Chlorpyrifos. Perhaps clearer if you exemplify with lead?
- Some references are missing, e.g. Spadaro and Rabl (2008). We suggest that a full list of references is included.

## Responses to Peer Reviewers' Comments on the Economic Calculator and Associated Guidance

| General comments | Response |
|---|---|
| **1. Comments on the purpose and the intended use of the calculator** | |
| **Elaborate on who will use the calculator and when the calculator may be used:** | Added the following text to the introduction of the methods document: "This document and the accompanying 'step-by-step' and economic calculator are intended for use by environmental and health professionals to rapidly characterize economic costs associated with chemicals exposures in the project countries. Results could be used in concert with other studies and observations to inform decisions relating remedial options and regulatory policy, among other applications." |
| **Add further guidance on how to use the calculator.** | The method introduction has been expanded to include intended users and interpretation of results. |
| **Focus on estimating cost of inaction for specific problems rather than country wide assessments of multiple pollutants:** | Columns have now been added to present the site specific cost. |
| **Pilot testing of the calculator.** | We have tried to do this as much as possible within the brief time frame of the project (Nov 21 - March 22). Multiple calls have been organized with all participating countries. as have calls with individual national consultants in Gabon, Kenya, Mali, Senegal, Tanzania and Zimbabwe. |

| | |
|---|---|
| **Make sure the calculator can be easily updated and revised** | The method document outlines the underlying assumptions and base equations. Using this document alone, a technical user should be able to run the calculations independent of the Excel document. Within the Excel document, hidden sheets can be accessed without a password, data are labelled, and references are provided in most cases. Additionally, certain cells have been described in additional detail with notes that can be viewed by rolling the mouse pointer over the cell. We agree that a second and more formal incarnation of this pilot product could benefit from a more standardized approach to updating and modifying equations. |
| **2. Comments on the content of the calculator and the supporting documents** | |
| **Merge the methods and the step-by step guidance?** | We are thankful for the observation but will opt to continue offering these as two separate documents based on input from the national consultants. |
| **Add some explanatory information to the excel calculator.** | As an alternative to providing more guidance in the Excel calculator, users are encouraged to reference the step-by-step and methods documents. In addition a recorded tutorial (English only) was produced as part of the effort. |
| **The quality of input data needs to be explicitly discussed.** | A section has been added to the methods document discussing sources of data |
| **The size and age of the exposed population:** | The reviewers highlight a number of concerns with how the exposed population is characterized in the calculator. These include comments regarding age and population size. With regard to the population size, this is a known source of uncertainty in the model. This has been made clear in the methods document and associated major assumptions annex. In addition the introduction of pre-defined population sizes and expanded guidance is intended to improve estimations. With regard to age, a conservative approach has been taken in quantifying IQ decrement. Specifically, while there exists some evidence that IQ decrement attributable to chemicals exposure can accrue into adolescence, most studies evaluate the period 0-5 or 0-7 years only. Because intellectual disability is the only sequalae assessed by the calculator, the age of a child is conservatively capped at 7. With regard to adults, the underlying methods make no distinction between age groups into adulthood relating to disease incidence. Thus any additional granularity in the calculator would not affect the results. Future efforts might endeavour to calculator more age specific sequalae. |
| **Modelling assumptions:** | |
| **The model is static rather than dynamic:** | The following text has been added to the methods introduction: 'Estimates are static and represent a snapshot in time.' |
| **Need for region specific data on values of DALY and IQ loss.** | IQ and DALY economic values have been calculated for each country based on 2019 country specific economic values. We agree that more study on the economic value of an IQ point (assumed here to be 2 % of lifetime |

| | |
|---|---|
| | earnings) and disability weights in this region would be beneficial. This is however outside the scope of the current effort. |
| | |
| **3. Comments on the presentation of modelling results.** | |
| **Present data sources, summary graphs, sensitivity tests and benchmarks:** | |
| **- A clear description of the data sources on pollution, including references to relevant studies** | This has been included in the newly added 'major assumptions' annex. |
| **- A summary (perhaps a flowchart?) of how the modelling was conducted.** | Basic flowcharts are presented in the methods document. |
| **- Illustrative diagrams of key results – templates could be created in additional excel sheets in the calculator** | This is an excellent suggestion. The spreadsheets have already been revised substantially under this phase of the project. Additional changes would be complicated to complete within the project's limited timeframe. |
| **- A sensitivity test so it is clear to the reader what drives the results. "Tornado diagrams" could be used to illustrate a simple one-way sensitivity test.** | It is agreed that this would be a useful exercise though is however outside the scope of this effort. |
| **Facilitate the presentation of monetary estimates alongside damages in physical terms.** | Physical damages are presented here vis a vis DALYs and IQ points. Future efforts could extract and present data on incidence of a given disease. |
| **Elaborate on how to communicate uncertainties and limitations associated with the data.** | |
| | |
| **Detailed comments** | |
| **The name of the country for which the calculation is being made should be clearly stated on each sheet of the calculator** | This has been added and populates automatically based on the selection on the first page. |
| **Include a weblink to the associated guidance documents on each sheet of the calculator.** | Agreed. However, the documents are not currently hosted online. |
| **It would also be user friendly to have a short instruction on each sheet.** | This has been integrated into the step-by-step |
| **Dietary sheet: Food** | We agree that a field for the scientific name - which could reference a pre-populated list of items - could be useful for future efforts. We feel that in the current context, the free text field allows for necessary flexibility. |
| **Dietary sheet: Weight ingested daily** | Thank you. Reference to the FAO guidance has been included in the methods. |
| **Step-by-Step Guidance** | |
| **"Population guidance"** | Thank you. Population guidance has now been included. |
| **Methods document** | |
| **Small errors in the example sheets on page 3.** | Thank you. These issues have now been corrected. |
| **Some references are missing,** | Thank you. These issues have now been corrected. |

# Annex 3. Peer review of the Risk and Vulnerability Calculator and associated guidance

## Terms of Reference

Objectives
The ultimate objective of this Terms of Reference is the peer-review of the economic and vulnerability calculators developed as part of the project 'Integrated Health and Environment Observatories and Legal and Institutional Strengthening for the Sound Management of Chemicals in Africa (African ChemObs)' (GEF ID 9080). The specific services required are described below in 'Provision of Services Required.'

*Background*
The overall objective of the African ChemObs Project is to contribute to improved health and environment protection through strengthening national and regional institutions, developing country owned plans of action and implementing priority chemicals and waste related interventions. The project seeks to develop a prototype of a national integrated health and environment observatory, including a core set of indicators enabling data aggregation, to provide timely and evidence-based information to predict, prevent and reduce chemicals risk to human health and the environment. More specifically, it addresses the necessary improvements to be made in the fields of awareness, knowledge, information management and communication on chemicals to support and provide an enabling framework for measures and actions to be taken.

Its implementation by project countries will contribute to improving capacity for data collection throughout the life cycle of chemicals; establishing an integrated health and environmental monitoring and surveillance system; reducing risks posed by chemicals and raising community awareness; a formal mechanism for intersectional coordination for health and environment; and improved understanding of the link between health and environment issues, to facilitate effective policymaking.
This project proposes to support the development of national observatories, capacity building of staff, support to identify causal pathways, risk ranking and priority settings, and activities to break links in causal pathways, thereby improving health and environment outcomes. The project has three components, which consist of the activities indicated below. Each component includes information on project activities, outcomes and outputs.

*Component 1*
Is focused on strengthening capacity of selected existing relevant national government departments and institutions to monitor pollution, prioritize areas for intervention as well as plan and implement solutions through active involvement of local communities.

*Component 2*
Is focused on the development of broad-based action plans to promote sound chemicals management and reduce negative impacts on health and the environment.

*Component 3*
This component will focus on the support for the sound management of chemicals in African countries to reduce risks from chemicals and wastes identified as posing specific risks to public health and environment.

Major headways were achieved on enhancing and strengthening institutional capacities for chemicals control and in term of risk and economic calculations. First, a Chemicals Risk and Vulnerability Calculator and an Economic Calculator have been developed to offer new tools to support national authorities towards a better estimation of the chemical risks prioritizing actions to be taken and estimation of the costs of certain chemicals on human health and the environment and support evidence-based decisions in chemicals management. The Chemical Risk and Vulnerability Calculator is designed to provide a relative risk assessment of different chemical pollutants, from point source (e.g. stores and contaminated sites) through pathway (water, soil, air, workplace) to receptors (population on site, public facility etc..).

The calculators are being tested and applied in nine African countries (Ethiopia, Gabon, Kenya, Madagascar, Mali, Senegal, Tanzania, Zambia, Zimbabwe). A prototype version of the ChemObs portal has been developed by UNEP MapX to help communicate the impact of interventions in a visually compelling way based on dynamic maps and dashboards.

These outcomes aim to provide an information and data management system that is making the best use of existing information while breaking new ground in combining available information in the most innovative and scientifically reliable manner. These Tools and methodologies will support UN Country teams and the countries to link environmental and chemicals management aspects into social and economic dimensions of SDGs. With the full integrated guidance being delivered, their testing in countries and first business cases for investment to prevent and reduce chemicals risks are now expected to be delivered in 2021.

### *Institutional Arrangement and Project delivery Process*

The World Health Organization and Africa Institute serve as executing agencies for the implementation of the Africa ChemObs project in Ethiopia, Gabon, Kenya, Madagascar, Mali, Senegal, Tanzania, Zambia and Zimbabwe.

## Provision of Services Required

### General Requirements

Pesticides Action Network, United Kingdom (PAN-UK) seeks a consultant to peer-review risk and vulnerability calculators and associated guidance developed as part of the UNEP implemented project 'Integrated Health and Environment Observatories and Legal and Institutional Strengthening for the Sound Management of Chemicals in Africa (African ChemObs)' (GEF ID 9080).The consultant should have extensive relevant technical expertise.

### Specific Deliverables and Proposed Timeline

The consultant will be responsible for delivering the following outputs by 1 December 2021.
Consolidated comments (General and specific) on the risk and vulnerability calculator and associated guidance documents;
Suggested corrections made in the calculator;

### Remuneration

The consultant will receive remuneration for time spent up to a maximum of three days' work at USD $420/day. Payment will be made upon acceptance of all deliverables.

| **Milestone** | **Payment** |
|---|---|
| Acceptance of all deliverables by PAN-UK | |
| **Max. Total** | **$1260** |

### *Evaluation Criteria*

Potential consultants will be evaluated against a short list of criteria provided below. These include minimum qualifications plus experience, which will be evaluated on a relative basis.

#### *Required minimum qualifications*

Relevant PhD, DrPH, MSc or equivalent;
Experience working in low- and middle-income country context (minimum 5 years);
Experience working on contaminated land issues (5 years);
Experience with GEF projects or UN organizations
Track record of relevant, published research or guidance;
Experience as a peer-reviewer

## Results of Peer Review of the PAN-UK Risk & Vulnerability Calculator

### *Summary by PAN UK*

PAN-UK engaged two experienced international consultants in chemicals management to review the Risk & Vulnerability calculator and associated guidance documents. The purpose of the review was to provide an independent assessment of whether the tool was effective for the intended purpose, whether it adds valuable functionality compared to existing tools, to validate the calculations themselves and suggest improvements either to the calculator or associated guidance resources. The consultants considered that calculations are sound and based on established methodology. They could see added value for the tool and considered that it could be of value to international agencies as well as national decision makers and project managers. They suggested new features / content for both the calculator and the guidance, which would increase the number of chemicals addressed and better support the interpretation of the data. In response, seven new chemicals have been added to the calculator along with new features to aid interpretation and new guidance resources.

The reviewers noted that the manual completion of the calculator is time consuming and considered that it would be much more likely to be used if it was automated in the MAPX system (this was also proposed by PAN-UK to UNEP in 2020).

It was pointed out that each chemical at a site is treated separately and then a total score for each site is a simple summation of scores for individual chemicals. An increasing body of evidence shows that mixtures of chemicals can interact and increase risks even further. While it would be straightforward to increase the risk score where certain combinations of chemicals are present, unfortunately the underlying interactions and impact on risks are complex and poorly understood and so this issue has not been addressed in the calculator at this time.

### *Report by Wouter Pronk and Russell Cobban, December 2021*

### *Introduction*

The Risk & Vulnerability calculator for the estimation of relative risks and vulnerabilities of contaminated sites, designed by PAN UK, was developed as part of the project *'Integrated Health and Environment*

*Observatories and Legal and Institutional Strengthening for the Sound Management of Chemicals in Africa (African ChemObs)'* (GEF ID 9080). The project is a partnership between UNEP, WHO and the Africa Institute.

The overall objective of the African ChemObs Project is to contribute to improved health and environment protection through strengthening national and regional institutions, developing country owned plans of action and implementing priority chemicals and waste related interventions.

The project seeks to develop a prototype of a national integrated health and environment observatory, including a core set of indicators enabling data aggregation, to provide timely and evidence-based information to predict, prevent and reduce chemicals risk to human health and the environment.

More specifically, the project addresses the necessary improvements to be made in the fields of awareness, knowledge, information management and communication on chemicals to support and provide an enabling framework for measures and actions to be taken and substantiate the ability to prioritize chemicals and waste management in the decision making process and facilitate integration into the national development plans and processes. ChemObs decision-making tools and processes include:

- The Economic Cost of Inaction Calculator (Pure Earth) to calculate the cost of inaction on chemicals management, with resulting units in DALYs.
- Risk & Vulnerability Calculator (PAN-UK) to calculate proportionate risk of chemicals exposure with site-level data, and to prioritize sites for intervention.
- MapX: a UNEP/GRID-Geneva web mapping platform to display results in the form of dashboards, and to assist pilot countries in calculations.

Nine pilot countries have been engaged in the project: Kenya, Tanzania, Senegal, Gabon, Ethiopia, Madagascar, Zimbabwe, Zambia, and Mali. (For more information see: https://chemobsafrica.org/ )

## *Aims of the Peer review*

For purposes of quality control PAN-UK has engaged two international consultants to review the Risk & Vulnerability calculator and provide consolidated comments (General and specific) on the calculator itself and associated guidance documents and suggest possible corrections and or improvements to be made in the calculator. To structure the review a series of twenty questions was provided by PAN-UK as shown in Table 1 below. It was, however, explicitly not the intention to limit the review to the provided set of questions. Comments on any aspect of the calculator and guidance was welcomed.

## *Overview of questions to structure the review*

| |
|---|
| Is the purpose of the R&V tool clear? |
| Is it clear who the R&V tool is designed for? |
| Is the tool effective for the intended purpose? |
| Does the tool add any functionality compared to existing tools? How valuable do you think this functionality would be in practice? |
| Can you suggest any changes to the tool that would improve its functionality? |
| How easy is it to use the tool? |
| How likely is it that the tool will be used in practice? Who by / in what context? |
| Can you suggest ways to make the calculator easier to use? |
| How clear is the guidance? |
| Does the guidance provide the right level of support to the new user? |
| Please provide any specific suggestions and identify any omissions to the guidance document |
| Please address corrections in the guidance document (track changes / comments) |

Is the language in the calculator clear? Is the meaning of each question clear?
Do the fixed responses make sense? Any missing?
Does the weighting of different criteria in the calculator make sense? Any suggested changes?
Are the calculations correct?
Is it clear how the final scores are derived?
Is it clear how scores for a whole site should be calculated?
Is it clear how results can be used / interpreted?
Any other comments or suggestions most welcome

## Review by Wouter Pronk

Based on thematical interlinkage, the provided questions are sometimes combined in one section in the text below and as a result numbered differently.

### *Is the purpose of the R&V tool clear? / Is it clear who the R&V tool is designed for?*

The user manual developed for the R&V tool clearly defines the purpose of the tool by stating 'We envisage that it will be used by national authorities to determine which sites / sources of chemical pollution to prioritise for risk reduction activities and for broader policy decisions concerning chemicals management.' The manual also states that the calculator tool makes use of a robust list of indicators covering important aspects of the potential environmental and social impacts of key chemical pollutants and is explicitly not intended to produce a definitive calculation of health or environmental risk, but rather intended to provide 'a relative calculation of risk based on the best available information.'

The statement that in the development of the calculator indices that can be derived from published data are prioritised (e.g. the open source web mapping platform MapX, developed by UNEP) and that data required from site visits, which is often lacking, are minimised, further explains the approach to create a widely applicable tool that can be already used when detailed site investigations have not (yet) been carried out.

However, as demonstrated in e.g. Site Question 9, Source Question 9 some basic forms of sampling analysis needs to be carried out. (Concentration of chemical (mg/kg) in contaminated land). Please note that contradictory to the intention that the calculator should run on public available data, the user manual assumes that some form of inventory and or analysis is already available. "This information usually comes from an inventory or assessment of a contaminated site." (Please see Section *Navigating the Calculator, page 6)*

The explanation of the tool's Source-Pathway-Receptor approach clearly illustrates that the R&V tool uses a common model of internationally best available practises of risk based site assessments.
At the ChemObs project website, where the calculator is introduced, the target audience of 'national authorities that want to determine which sites / sources of chemical pollution to prioritise,' is less clearly explained.[10] The guidance video provided at the site also dives directly into a technical explanation and maybe should have briefly mentioned the intended target audience, assuming that many internet users start watching available video content before downloading a user manual.

Is the tool effective for the intended purpose? / Does the tool add any functionality compared to existing tools? How valuable do you think this functionality would be in practice?
To answer the question whether the tool is effective for the intended purpose and adds functionality to existing tools, one should clearly focus on the target audience and its needs to have a better understanding of

[10] https://chemobsafrica.org/guidance/risk-and-vulnerability-calculator/

the risks of a particular site (or a series of sites) for public health (focussing on vulnerable groups within affected communities) and the environment.

As mentioned in the user manual, the calculator is designed for national authorities who want to determine which sites / sources of chemical pollution to prioritise for risk reduction activities and for broader policy decisions concerning chemicals management. The sites may have the character of a point source pollution (e.g. stores and contaminated sites) and or the character of more diffuse pollution (e.g. pesticides in use, mercury in artisanal mining).

The target audience is explicitly not the national agency responsible for carrying out a national POPs pesticides inventory. For them FAO Environmental Management Toolkit for Obsolete Pesticides methodology, referenced in the user manual, provides the Rapid Environmental Assessment (REA) to narrow down contaminated sites to be selected for site investigation and  the Pesticide Stockpile Management System (PSMS), a web based application to be used by countries to record and monitor their inventories of pesticides and their usage, in order to assist them in managing the most efficient usage.[11]

Although the calculator includes some tracking elements for pesticides in use, the target audience is also not explicitly organisations with the aim to reduce health and environmental risks from pesticides in actual farming practices, such as the Toxic Load Indicator for pesticides in use, referenced in the manual. However, an ambition to develop this direction further is indicated by PAN UK by asking stakeholders interested in tracking risks from actual use to contact the organisation.

Finally, the target audience is also not an governmental or civil society organisation focusing on a wide range of contaminants in contaminated land and the aim to quantify and rank toxic exposures in Low and Middle Income Countries worldwide, such as it is the case for the referenced Blacksmith Index for Contaminated Sites.

As a result the target audience is expected to have concerns about one or a series of sites varying from not properly contained pesticides stocks that are stored in not well maintained stores, to sites that clearly show signs of serious soil contamination. Furthermore, the target audience might have an interest to track risks from pesticides in use. The target audience is expected to have limited budgets available for sampling and analysis when the concerns about the site(s) are raised.
The R&V tool is expected to provide this target audience of national authorities with a valuable first indication on whether they should be concerned and look for possible resources to further research the contamination and possible ways for mitigating the risks for public health and the environment.

### *How easy is it to use the tool? / Can you suggest ways to make the calculator easier to use? / Does the guidance provide the right level of support to the new user?*

Based on the explanations in the user manual and the guidance video available from the ChemObs website, the tool is easy enough to use. It should be mentioned, however, that user identification procedures of MapX were rather unclear. Furthermore, it is not very convenient that the user has to open MapX for data collection next to the calculator, instead of being linked to the intended section of MapX directly from the calculator, when filling in the data. Direct links from the calculator to MapX when MapX data are required are expected to make the calculator easier to use. Real integration of the calculator with MapX in the future would further strengthen the user friendliness.

[11] In recent years there was some unclarity about FAO's future plans with PSMS and the web based version from the tool is currently not available on the internet.

*How likely is it that the tool will be used in practice? Who by / in what context?*

With a clear target audience of national authorities from ChemObs countries, that are expected to have concerns about potentially contaminated sites in their countries and that are also expected to be wanting to determine which sites / sources of chemical pollution to prioritise for risk reduction activities, it seems fairly likely that the tool will be used in practice. However, in order to demonstrate the practical value of the calculator – and to draw lessons from actual practical use, it will be important to organise pilot (training) sessions with real national authorities from ChemObs project countries. An pilot with a large variety of national and maybe also local authorities will demonstrate how valuable and practical the real target audience the calculator will find.

*Please provide any specific suggestions and identify any omissions to the guidance document / Please address corrections in the guidance document (track changes / comments)*

The Key reference: [https://www.pureearth.org/wp-content/uploads/2014/12/Blacksmith-Index-An-Overview.pdf](https://www.pureearth.org/wp-content/uploads/2014/12/Blacksmith-Index-An-Overview.pdf) does not work.

The User manual refers in the text to the "FAO EMTK methodology for contaminated sites". In the link the reader is forwarded to EMTK Volume 1., that is not about contaminated sites but about environmental risk tracking, prioritization of stores and about regional prioritization and risk tracking. Volume 1 describes, amongst others, the use of PSMS in support of obsolete pesticides national inventories, safeguarding and disposal activities. As PSMS is also a tracking tool, it is assumed that the reference to Volume 1 is correct and that the title in the manual should be corrected.

The guidance document is clear and easy to read. I have not “tracked” any comments or corrections.

*Is the language in the calculator clear?/ Is the meaning of each question clear?/ Do the fixed responses make sense? Any missing?*

In general the language in the calculator and the meaning of questions are clear. The explanatory notes in the explanation field support the understanding of the logic behind the calculator well.

A bit more consistency would strengthen the user friendliness. Suggestions where to find the relevant data are not always provided at the same place int the Excel sheet of the calculator. It will probably add to the user friendliness of the tool if you would consequently use the column **Data details / Units / Pull Down Menu Choices** to explain where you suggest that the data can be found  e.g. MapX, Google Earth, local available data… and the column

**Explanation** to illustrate why the question is important and how it can affect risks.

Moreover, the indication that a cell should not be touched appears as both “Site question” and   “RQ1 is a site question. Cells will fill automatically from site question sheet. Do not touch.” at different places in the calculator. It will be probably clearer when you use one formulation, preferably the formulation with the most explanation and consequently used at the same place under the Explanation column.

If you want to include target audiences with no possibility to carry out any form of analysis, references in the site questions to inventories, sampling and analysis should be accompanied by a disclaimer like comment like “when available”. Otherwise those target groups might decide that the tool is not designed for them.

The fixed responses work very well. No missing responses were found. PQ8, PQ9 and PQ10 miss some bold marked question dividing gridlines.

Does the weighting of different criteria in the calculator make sense? Any suggested changes?
The weighing of different criteria throughout the calculator questions seem logical. The weighing criteria do increase in line with the expected increase in risks for health and the environment. The practical examples in the *Additional site info* tab work well and although a store stocked with containers that are in an excellent condition, is not expected to cause concern from national authorities, the example functions as a suitable reference point in the calculator.

### *Are the calculations correct?*
No mistakes were found, when going through the calculations.

### *Is it clear how scores for a whole site should be calculated?*
It is clear that for every chemical contaminant of concern a separate entry should be made. It is unfortunate the no account can be taken of possible interaction between the chemicals. If there is indeed ' a growing body of evidence that pesticides can become more harmful when combined'[12] (although the effect has not been studied in enough detail), one maybe could flag the cocktail effect in the calculator when more chemicals are entered for one site as an indication of expected higher risk.

### *Is it clear how results can be used / interpreted?*
The fact that there is no reference parameter or an explanation of how one should interpret the results makes it difficult to evaluate the results of the calculation. The results are a calculated number for the *Relative risk to human health* and a calculated number for the *Relative risk to environment*. It is, however, difficult to understand how one should read those numbers apart from the relative risk positioning shown in the graph that is included in the summary results indicating: "Example site 2: highest risk for Health" and "Example site 3: highest risk for Environment."

It seems that the target group of national authorities would be better supported if they not only could prioritise between sites of concern, but also would obtain some more information on the risks from identified sites of concern for health and the environment.

If the calculator would produce a clearer indication that the identified site(s) pose risks to public health and the environment and that further investigations should be seen as a priority for the country to avoid higher costs in the future, the tool could function more effectively as a well accessible tool for policy making.

Would it be possible to flag or label the provided data in the Site questions tab as for instance for container condition:
**A: "Moderate"** , **B: "Poor"** or **C: "Very poor"** with some following basic management instructions?
**A:** Monitoring plan of stocks required to avoid future risk for health and the environment;
**B:** Monitoring plan of stocks and repackaging of leaking containers and packaging material required to avoid future risk for health and the environment;
**C:** Site investigations required to establish current risks for health and the environment and the development of an associated short and longer term management plan to remediate the site.
There are more places in the calculator where the provided data that for instance a **water well is present within 100 meter** could give a clear indication of potentially high risks. Would it be possible to flag that risk with a :

Own in [12] https://www.pan-uk.org/the-cocktail-effect/

Urgent risk for drinking water pollution. Site investigations required to establish current risks for health and the environment and the development of an associated short and longer term management plan to remediate the site

If the inclusion of such labels in the calculator would be technically feasible without over complicating the existing design, it is expected to provide extra practical value to the target group of national authorities responsible for the issue that do not have large resources and extensive budgets to manage such sites.

Other comments or suggestions

It is suggested to use a decimal separator in the entire excel file of the calculator.

## Review by Russell Cobban

Answers to the questions are provided in the table below, in addition to which comments and edits have been provided to the directly to the calculator spreadsheet and associated guide.

| | |
|---|---|
| | Is the purpose of the R&V tool clear?<br>The guidance document could be more specific to users as opposed to project managers<br>Perhaps insert into the guidance:<br>Background<br>Assume no previous knowledge of indicators or risk calculators. Guideline should focus on the user – less emphasis for justification for use to project manager. There should be a discussion of the tool's necessity. Some detail required of the other tools (Blacksmith, PSMS, REA etc.) and why they are not relevant / need improvement. Provide detail of the whole tool including the economic indicator.<br>Objectives<br>Audience<br>Presentation |
| | Is it clear who the R&V tool is designed for?<br>See above comments |
| | Is the tool effective for the intended purpose?<br>Yes – potential uses could be more clearly defined in the guidance. |
| | Does the tool add any functionality compared to existing tools? How valuable do you think this functionality would be in practice?<br>Yes, there is added functionality. REA and BI are focussed on contaminated sites. This tool, using the source / pathway / receptor model as a framework, is able to give an indication of risk to a wider range of media. |
| | Can you suggest any changes to the tool that would improve its functionality?<br>Please read the attached comments on the spreadsheet. Also:<br>Develop the tool with all ideal data fields for potential collection, including for example, field exposure measurements, environmental receptor data, environmental measurement data. This would make provision for data to be added when if it comes available.<br>Calibrate the tool using developed world data or from an area in the world where there has been an extensive study for many years. Perhaps Agent Orange in Vietnam, for example? This site or study could be used as base comparison.<br>Give an indication of how far every calculation is away from the ideal in terms of data completion. |

| | |
|---|---|
| | Note that more data does not mean higher risk – there is a need to be able to improve granulation of data without necessarily increasing the risk.<br><br>Add more contaminants (for example):<br>Uranium<br>Arsenic<br>Tributyltin<br>Benzene<br>Total petroleum hydrocarbon (Aliphatic)<br>Total petroleum hydrocarbon (Aromatic)<br>All dioxin and furans<br>Cyanide<br>Link D7 pathway and source cells. |
| | How easy is it to use the tool? At the moment it is not very practical. There are too many fields to fill from different sources. An excel based tool / spreadsheet environment is difficult to use. |
| | How likely is it that the tool will be used in practice? Who by / in what context?<br>UN agencies or other organizations designing future projects<br>People undertaking Environmental Management Planning for substances for which there is no existing assessment tool.<br>Personnel attempting to gauge the risk level of different pollutants<br><br>I am not sure that this is the best forum for the 'pesticide in use' calculation to demonstrate pesticides in use as a cause for concern. Other stakeholders would argue that these chemicals have been approved by Govt agencies and, therefore, require different treatment. This use for such calculations is untested and the licencing and use of pesticides is beyond the scope of this type of work. |
| | Can you suggest ways to make the calculator easier to use?<br>Cascade the questions so that users can only see ones that are relevant.<br>Remove superfluous information that users don't understand or need immediately.<br>Remove users from the calculation element so that they only see a 'result'.<br>Change the medium of use to make it form based.<br>Insert a macro to clear all data instead of having to delete each relevant cell – this will also help to eliminate data insertion errors. |
| | How clear is the guidance?<br>Please see edits, particularly to the introduction. |
| | Does the guidance provide the right level of support to the new user? See previous comments, less focus needs to be made on justifying the work to project managers. Possibly there might be a way of writing a 'quick start guide'. Have more detailed technical information in an appendix. |
| | Please provide any specific suggestions and identify any omissions to the guidance document<br>Please see edits, particularly to the introduction |
| | Please address corrections in the guidance document (track changes / comments) – See attached document |
| | Is the language in the calculator clear? Is the meaning of each question clear? Some of the variable names need to be changed to a question. |
| | Do the fixed responses make sense? Any missing? Fixed responses should be removed. Reference to the guidance could be added to explain weightings and any fixed responses. |

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| | |
|---|---|
| | Does the weighting of different criteria in the calculator make sense? Any suggested changes? Receptor scores for the environment need more emphasis |
| | Are the calculations correct? Seemingly. |
| | Is it clear how the final scores are derived? Yes. |
| | Is it clear how scores for a whole site should be calculated? Yes, but as mentioned previously this is a bit convoluted. |
| | Is it clear how results can be used / interpreted? Yes, once a library of assessments is available it will be easier to see which sites are low and high risk and therefore be easier to interpret. Stand-alone data results have no reference and therefore no / limited comparisons can be made. |
| | Any other comments or suggestions most welcome As discussed during the meeting of 10/12/21, the summary spreadsheet could be adapted to highlight the main issues regarding each site. This sheet would also highlight any particular risks that have come to light, as suggested by Wouter. |

## Response to review

| | Reviewer's comment | Response |
|---|---|---|
| 1 | Please note that contradictory to the intention that the calculator should run on public available data, the user manual assumes that some form of inventory and or analysis is already available. | The guidance has been revised to make the intention clearer. The intention is not to base calculations entirely on publicly available data, since an understanding of which chemicals are present at a site and the potential scale of release into the environment are an essential minimum for any meaningful calculations. However, the calculator and the MAPX system pull together a wide range of information about the site from publicly available sources in order to significantly enhance a very basic minimum data requirement from the site |
| 2 | it is not very convenient that the user has to open MapX for data collection next to the calculator, instead of being linked to the intended section of MapX directly from the calculator | Agreed. The automation of the system in MAPX would greatly enhance the efficiency of running calculations. This has been requested of UNEP. |
| 3 | it will be important to organise pilot (training) sessions with real national authorities from ChemObs project countries. | This has been done |
| 4 | Link to key reference does not work | Links and references amended in latest guidance |
| 5 | A bit more consistency would strengthen the user friendliness | This has been addressed in the calculator |

| | | |
|---|---|---|
| 6 | It is unfortunate the no account can be taken of possible interaction between the chemicals | True. This is very possible to incorporate into the calculations. The limitation is the understanding of how the many possible combinations might impact risk. This was beyond the scope of the current exercise |
| 7 | The fact that there is no reference parameter or an explanation of how one should interpret the results makes it difficult to evaluate the results of the calculation. | New guidance resources have been developed to address this |
| 8 | Would it be possible to flag or label the provided data in the Site questions tab as for instance for container condition | Yes, very practical suggestion now done. See [17] |
| 9 | The guidance document could be more specific to users as opposed to project managers | This has been addressed by developing a new document for project managers and removing some of the text from the user manual. |
| 10 | Develop the tool with all ideal data fields for potential collection, including for example, field exposure measurements, environmental receptor data, environmental measurement data. This would make provision for data to be added when if it comes available. | This comes back to the question of integrating the calculation in MAPX, above [2] |
| 11 | Calibrate the tool using developed world data or from an area in the world where there has been an extensive study for many years. | This would be very useful, but beyond the scope of the current project |
| 12 | Add more contaminants | Done as suggested |
| 13 | How easy is it to use the tool? At the moment it is not very practical. There are too many fields to fill from different sources. An excel based tool / spreadsheet environment is difficult to use. | See [2] |
| 14 | Can you suggest ways to make the calculator easier to use?<br>Cascade the questions so that users can only see ones that are relevant.<br>Remove superfluous information that users don't understand or need immediately.<br>Remove users from the calculation element so that they only see a 'result'.<br>Change the medium of use to make it form based. | The calculator has been simplified to address this to the extent possible, but these issues would be entirely addressed by [2]<br><br>Users do not engage with the calculation, but they can see how it was derived<br><br>The format of the 'site questions' is form based as the only section requiring locally derived data. The rest of the calculator was intended to be integrated with MAPX |
| 15 | Insert a macro to clear all data instead of having to delete each relevant cell – this will also help to eliminate data insertion errors. | Done |

| | | |
|---|---|---|
| 16 | Is it clear how results can be used / interpreted? Yes, once a library of assessments is available it will be easier to see which sites are low and high risk and therefore be easier to interpret. Stand-alone data results have no reference and therefore no / limited comparisons can be made. | Indeed. However, a fictional 'benchmark site' has been added in order to address this issue |
| 17 | As discussed during the meeting of 10/12/21, the summary spreadsheet could be adapted to highlight the main issues regarding each site. This sheet would also highlight any particular risks that have come to light, as suggested by Wouter. | Agreed. 'Red flag' issues are now highlighted in the calculator and added to the summary page (see [8]) |

# Annex 4. The weighting of different variables in the Risk and Vulnerability Calculator

Each of the components of the source, pathway and receptor information is allocated a score in the calculator based on the numerical value multiplied by a weighting factor. Higher risk factors are weighted more heavily than lower risk ones, as shown in Table 6. The weightings were allocated based on similar scoring systems in existing tools, such as the Blacksmith Index and the Toxic Load Indicator, to the extent possible. There was no opportunity to validate assumptions and weightings with actual exposure data, but this would be a valuable next step. The reason children are weighted more heavily, for example, is because of their greater vulnerability to the health impacts of chemical exposure compared to adults. Women of reproductive age are weighted more heavily because of their greater vulnerability in pregnancy, the vulnerability of their child in utero and the greater burden of care if their child's health is adversely affected.

*Asterisked source variables are based on Toxic Load Indicators and the methodology for deriving the scores is described in the Risk and Vulnerability Guidance document and in the source material Microsoft Word - Toxic Load Indicator methodology_final_260617 (pestizidexperte.de). The basis for these are existing classifications by the WHO, GHS, the US EPA or classifications suggested by the Footprint Database Project. The scale ranges from 1 point to 10 points for the highest toxicity/strongest effect, with five different grades in the order 1-2-5-8-10. A score of five is used in case no data for the specific parameter is available (default value)

*Table 6. Showing the weighting of different components of the calculation*

| Source variables | Weighting | Pathway variables | Weighting | Receptor variable | | Weighting |
|---|---|---|---|---|---|---|
| The primary source information concerns the concentration of the chemical (whether contained, uncontained or in contaminated land). This is combined the following factors: | | Workers on the site wear suitable PPE | 1-3 | In direct contact with the chemical at the site | Men (over 14 years) | 3 |
| Volume of contained chemical | 1 | Frequency of exposure of workers on the site | 100-500 | | Women aged 14-45 | 6 |
| Container condition (for stored chemicals) | 0.5 – 1 | For pesticides in use; application method | 1-3 | | Women aged over 45 | 3 |
| Quantity of uncontained chemical | 1 | Rainfall | <50mm=1; 50-249=2; 250-499=3; 500-999=4; 1000-2000=5 | | Children (under 14 years) | 9 |
| Area of contaminated land | 1-5 | Groundwater / shallow aquifer | 1 or 3 | Living within 100m of the site | Men (over 14 years) | 2 |
| The following scores depend on which chemical is present | | Flood plain? | 0 or 2 | | Women aged 14-45 | 4 |
| *Acute toxicity | 1-10 | Type of closest water body | 1,3,5 | | Women aged over 45 | 2 |
| *Carcinogenicity | 1-10 | Proximity of water body (within 100m or not) | 0 or 3 | | Children (under 14 years) | 6 |
| *Mutagenicity | 1-10 | Topsoil type | 1,2 or 3 | | | |
| *Reprotoxicity | 1-10 | Land use | 1,2,3,8 | | | |
| *Acceptable Daily Intake | 1-10 | Type of public facility within 100m | 0,2,3,4 | Living 100-500m from the site | Men (over 14 years) | 1 |
| *Toxicity aquatic organisms | 1-10 | Prone to natural disaster? | 0.3 | | Women aged 14-45 | 2 |
| *Toxicity bees | 1-10 | % land covered in vegetation; Sparse (<15%) or >15% | 1,2 | | Women aged over 45 | 1 |
| *Bioaccumulation | 1-10 | Mean temp in degrees celsius Jan-March; Aug-Oct | 0.5, 1,2 | | Children (under 14 years) | 3 |
| *Persistence | 1-10 | Land use attenuation factor, food | 1,2,5 | Receptors in the environment | Aquatic organisms | 1 |
| *Volatility | 1-10 | | | | Honeybees | 1 |
| *Half life on plants | 1-10 | | | | | |
| *Solubility in water | 1-10 | | | | | |

# Annex 5. Calculations for the Risk and Vulnerability Calculator

*Table 7. Calculations for Relative Risk to Human Health*

| | Source | Toxicity | Physical props | Pathway | Receptor | Risk scores |
|---|---|---|---|---|---|---|
| Direct exposure pesticides in use | Volume x concentration x area sprayed | Sum of TLI scores for mammalian toxicity | Not included | Scores for PPE use and method of application | Scores for people spraying pesticide | Multiply each score in the row |
| Direct exposure contaminated sites or stocks | Container condition (volume x concentration) Area of contaminated land | See above | Not included | Scores for PPE use and frequency of occupational exposure | Scores for population on site in direct contact | Multiply each score in the row |
| Water | See above | See above | Score for leaching and persistence | Sum scores for rainfall, ground water, flooding, proximity of water body, topsoil | Sum of scores for people living within 100m and 100-500m | Multiply each score in the row |
| Soil | See above | See above | See above | Sum scores for land use, public facilities, natural disasters, % vegetation | See above | Multiply each score in the row |
| Air | See above | See above | Score for volatility | Score for mean temperature Jan-Feb and Aug-Sept | See above | Multiply each score in the row |
| Food | See above | See above | Scores for bioaccumulation and half-life on plants | Land use attenuation factor | See above | Multiply each score in the row |
| **FINAL HEALTH RISK SCORE** | | | | | | Sum all risk scores x 0.00001 |

*Table 8. The calculations for the Risk and Vulnerability Calculator relative risk to environment*

| | Source | Toxicity | Physical props | Pathway | Risk scores |
|---|---|---|---|---|---|
| Water | Scores for quantity of chemical (concentration x volume or land area) in containers, uncontained, contaminated land or sprayed pesticide | TLI score for toxicity to aquatic organisms | Score for leaching and solubility | Sum scores for rainfall, ground water, flooding, proximity of water body, topsoil | Multiply each score in the row |
| Soil | See above | TLI score for toxicity to honeybees | Score for leaching, persistence and solubility | Sum scores for natural disasters, % vegetation | Multiply each score in the row |
| Air | See above | TLI score for toxicity to honeybees | Score for volatility | Score for mean temperature Jan-Feb and Aug-Sept | Multiply each score in the row |
| **FINAL ENVIRONMENT RISK SCORE** | | | | | Sum all risk scores x 0. 001 |

# Annex 6. Site Questions Sheet for the Risk and Vulnerability Calculator

| ID | Variable Name | Data Details / Pull Down Menu Choices | Data input | Explanation |
|---|---|---|---|---|
| | | **Site Questions**<br>This sheet describes the minimum information that is required to run the calculations | | |
| **Site Q1** | **GPS coordinates of the site or target area** | **Latitude** | **14.46166** | Please use decimal degrees to at least 5 decimal places (3m). There are various free converters to be found online if you want to move from degrees, minutes and seconds to the decimal e.g. https://www.latlong.net/degrees-minutes-seconds-to-decimal-degrees. |
| | | **Longitude** | **28.42083** | |
| | **Site Name** | **Optional** | **Test** | Use a unique identifier for the site. |
| SQ1 | Chemical at the site | See Data sheet and drop down menu for the list of chemicals currently available in the calculator. | Dinoseb | |
| SQ2 | Which category or categories best describe the chemical? Answer all that apply. | Stored chemical =A | yes | •A = For stored chemicals answer questions SQ3, SQ4, SQ5 |
| | | Uncontained chemical =B | no | •B = For uncontained chemical answer questions SQ6, SQ7 |
| | | Contaminated land = C | no | •C = Contaminated land answer SQ8 and SQ9 |
| | | Pesticide in use= D | no | •D = Pesticide in use on crops answer questions SQ10, SQ11, SQ12 |
| SQ3 | A: Quantity of chemical in containers | kg or litres | 5000 | |
| SQ4 | A: Concentration of contained chemical | g/l or g/kg | 0.05 | |
| SQ5 | A: Container condition | Excellent | 0.1 | See 'additional site info' tab for additional information on container condition |
| | | Good | 0.2 | |
| | | Moderate | 0.3 | |
| | | Poor | 0.8 | |
| | | Very poor | 1 | |
| | | | 0.2 | |
| SQ6 | Please skip this question, not relevant | kg or litres | 0 | See 'additional site info' tab for information on uncontained chemicals |
| SQ7 | Please skip this question, not relevant | g/l or g/kg | 0.001 | This information would need to come from analysis of the uncontained chemical. |

| | | | | |
|---|---|---|---|---|
| SQ8 | Please skip this question, not relevant | •<100m2 = 1<br>•100 – 1,000 m2 = 2<br>•1,000 – 10,000 m2 = 3<br>•1 hectare – 5 hectares = 4<br>•> 5 hectares = 5 | 5 | For artisanal mines and industrial sites, the area of the site may be approximated from Google Earth images |
| SQ9 | Please skip this question, not relevant | mg/kg | 0 | This needs to be a best estimate average for the contaminated area, based on sample analysis. |
| SQ10 | Please skip this question, not relevant | litres or kg | | These figures may not be availabe for the full range of pesticides on the market, but some valuable data may be available for certain crops e.g. procured by government departments or parastatals, often in relation to commodity crops e.g. coffee, cotton or outbreak pests, such as locusts, quelea or armyworm. |
| SQ11 | Please skip this question, not relevant | g/l or g/kg | | This information may be obtained from the product label and/or from the manufacturer or from sample analysis |
| SQ12 | Please skip this question, not relevant | ha | | For area under particular crops, estimates may be based on national data or FAO Agro-Maps. National data is often available for commodity crops, for example, where pesticide purchasing is done centrally and data on area under the crop, number of applications, distribution is available. Unfortunately, this data may only available for a limited number of crops, if at all, but it is valuable nonetheless. |
| PQ1 | Do workers wear suitable PPE? | • Yes, all workers wear suitable PPE (1)<br>•More than 50% workers wear suitable PPE (2)<br>•Few workers wear any suitable PPE (3) | 1<br>2<br>3 | |
| | | | 1 | |
| PQ2 | Frequency of workers' direct contact with chemical | Frequent contact due to regular, occupational use<br>Occasional contact due to accidental spills or infrequent use<br>Rare contact due to occasional handling or spills | 500<br>200<br>100 | |
| | | | 100 | |
| PQ3 | For pesticide users, what is the most common application method? | •Tractor-mounted spray boom = 1<br>•Backpack sprayer =3<br>•Low volume sprayer (ULV / CDA)=2<br>•Improvised equipment=3 | | If you are not entering figures for a pesticide in use, you can skip this question. Don't worry about which value is in the box, as the figure will be multiplied by SQ10, which is zero in this case. Please note that the calculator is not yet developed for aerially sprayed pesticides. |

| | | | | |
|---|---|---|---|---|
| | | •Improvised equipment = 3 | | |
| RQ1 | Number of workers in direct contact with chemical e.g. store workers, pesticide users, artisanal miners | Men (over 14 years) | 2 | **THIS REFERS ONLY TO PEOPLE WORKING DIRECTLY IN CONTACT WITH THE CHEMICAL ON THE SITE** |
| | | Women aged 14-45 | | |
| | | Women aged over 45 | | |
| | | Children (under 14 years) | | |

# Annex 7. List of chemicals added to the Risk and Vulnerability Calculator

| Industrial chemicals | Pesticides | Pesticides | Pesticides | Pesticides | Pesticides |
|---|---|---|---|---|---|
| Asbestos | 2,4,5-T | Carbosulfan | Dinoseb | Malathion | Pendimethalin |
| Arsenic | 2,4-D | Chlordane | DNOC | Mancozeb | Pentachlorophenol |
| Benzene | Alachlor | Chlorfenvinphos | Edifenphos | MCPA | Phosphamidon |
| Cyanide | Aldicarb | Chlormequat chloride | Endosulfan | Mepiquat chloride | Profenofos |
| HCB (hexachlorobenzene), | Aldrin | Chlorpyrifos | Ethephon | Methamidophos | Prometryn |
| HCBD (Hexachlorobutadiene) | Amitraz | Copper oxychloride | Ethylene dibromide | Methiocarb | Propargite |
| Mercury methyl | Atrazine | Cyanide | Fenamiphos | Methomyl | Propoxur |
| Mercury metal | Bendiocarb | Cyhalothrin | Fenitrothion | Methyl bromide | Tebupirimifos |
| Lead | Benomyl | Cyhalothrin, gamma | Fenthion | Metolachlor | Temephos |
| PCB | Bentazone | Cypermethrin | Fenvalerate | Metribuzin | Tetradifon |
| PCDD (polybrominated dibenzo-p-dioxin) | Benzene | DDT | Fluazifop-P-butyl | Monocrotophos | Thiodicarb |
| PeCB (pentachloro-benzene) | Binapacryl | Deltamethrin | Glyphosate | Nicosulfuron | Thiram |
| Total petroleum hydrocarbon (aliphatic) | Bromoxynil | Diazinon | Hexchlorocyclohexane | Paraquat | Toxaphene |
| Total petroleum hydrocarbon (aromatic) | Captafol | Dicofol | Imidacloprid | Paraquat dichloride | Triadimenol |
| Pyrolusite. | Carbaryl | Dieldrin | Lambda-cyhalothrin | Parathion | Tributyltin |
| Uranium | Carbofuran | Dimethoate | Lindane | Parathion-methyl | Trifluralin |

# Annex 8. Kenya Results of Risk and Vulnerability Calculations

The Kenya consultants used data from 32 sites contaminated with lead and mercury, DDT and PCBs. Three sites emerged as very high risk scores for health and environment (circled in red in Figure x). These sites are Kayole Informal ULAB Recycling Area, AP Lead Acid Battery Recycling Company and Dandora Municipal dumpsite. They are all located in densely populated urban areas. Despite having been decommissioned, the Kitengela Obsolete chemicals storage site had a high risk score, ranked fourth out of the 10 most polluted sites.

*Table 8. showing results for sites in Kenya*

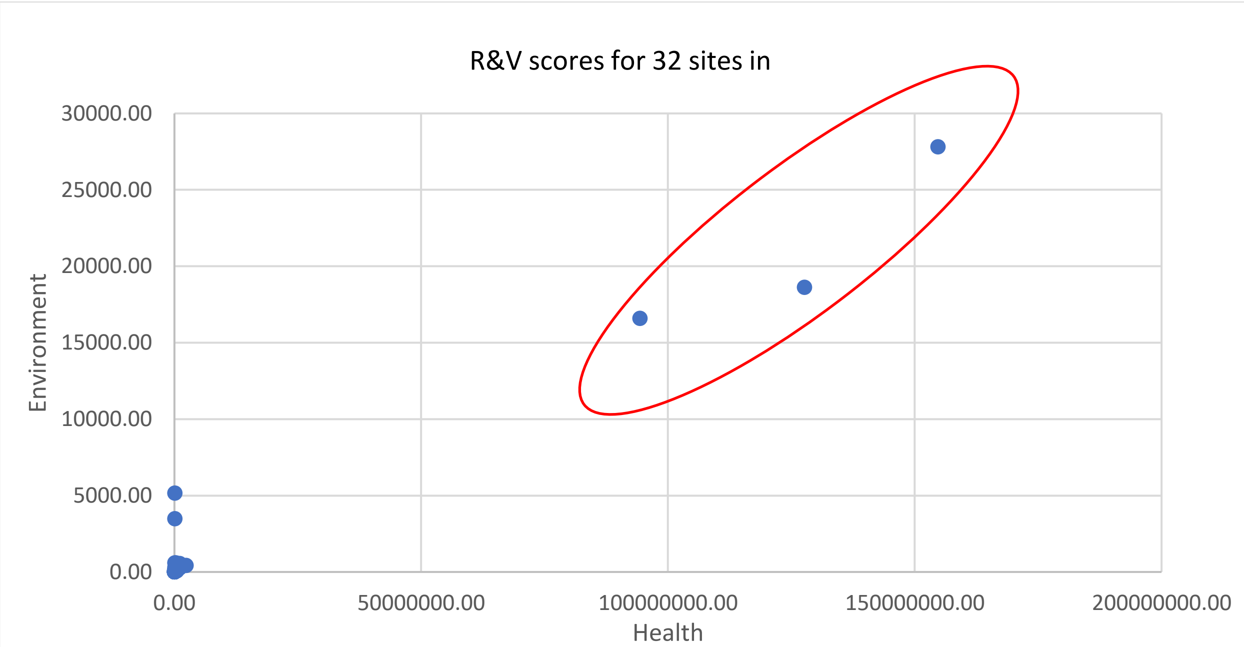
| Your name | Date | Site name | Latitude | Longitude | Chemical | Relative risk to human health, by chemical | Relative risk to environment, by chemical | Total site score for relative risk to human health | Total site score for relative risk to environment |
|---|---|---|---|---|---|---|---|---|---|
| Fred-rick | 29/7/20 | Rosterman Artisanal Goldmines | 0.2594444 | 34.736667 | Mercury metal | 4736.78 | 0.18 | **4736.78** | **0.18** |
| Fred-rick | 30/7/20 | Ndira Artisanal Goldmine site | 0.051389 | 34.3434278 | Mercury metal | 2502.73 | 0.13 | **2502.73** | **0.13** |
| | | Rongo Artisanal Goldmines | -0.746654 | 34.5595926 | Mercury metal | 1620.78 | 0.13 | **1620.78** | **0.13** |
| | | Voi Municipal Dumpsite | -0.746654 | 38.460051 | Mercury metal | 2867.43 | 135.86 | **2867.43** | **135.86** |
| | | Osiri Artisanal Goldmines | -0.988546 | 34.265813 | Mercury metal | 5832.56 | 0.20 | **5832.56** | **0.20** |
| Fred-rick | 08/3/20 | Sugar Factory & AgroChemicals, Muhoroni area | -0.15552 | 35.188 | Lead | 1435.38 | 9.22 | **1435.38** | **9.22** |
| | | Bungoma Municipal Dumpsite | -0.15552 | 35.188 | Lead | 647.15 | 0.16 | **647.15** | **0.16** |
| | | | | | | | | | |
| | | Gikomba Jua Kali Fabricators | -1.2897 | 36.8414 | Lead | 1038283.87 | 251.51 | **1038283.87** | **251.51** |
| | | Olkaria Geothermal Power Plan | -0.893676 | 36.308777 | Lead | 1804.60 | 1.75 | **1804.60** | **1.75** |
| | | Toi Market | -1.307 | 36.78 | Lead | 6944.65 | 6.68 | **6944.65** | **6.68** |
| | | Nzoia Sugar factory | 0.56899 | 34.655 | Lead | 4632.28 | 20.36 | **4632.28** | **20.36** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mumias Sugar Company | 0.35996 | 34.4991 | Lead | 1436.53 | 0.45 | **1436.53** | **0.45** |
| | | Dandora Dumpsite | -1.25 | 36.900002 | Lead | 93105468.14 | 16537.70 | | |
| Fred-rick | 08/4/20 | Dandora Dumpsite | -1.25 | 36.900002 | Mercury metal | 1203172.16 | 46.16 | **94308640.30** | **16583.86** |
| | | AP Lead Acid Battery Recycling Company | -1.313979 | 36.879564 | Lead | 127674775.02 | 18628.51 | **127674775.02** | **18628.51** |
| | | Korogocho lead-acid battery recyclers and metal smelters | -1.429444 | 37.4925 | Lead | 2389502.36 | 425.17 | **2389502.36** | **425.17** |
| | | Ganesh Informal ULAB Recyclers | -0.785333 | 36.5223667 | Lead | 97885.05 | 5159.23 | **97885.05** | **5159.23** |
| | | Pioneer jua kali | -0.723642 | 37.1637708 | Lead | 75405.83 | 587.22 | **75405.83** | **587.22** |
| | | Kariokor Elecronic Cable and Tire Burning Area | -1.281915 | 36.832945 | Lead | 1055818.20 | 541.87 | **1055818.20** | **541.87** |
| | | Kayole Informal ULAB Recycling Area | -1.267863 | 36.9149933 | Lead | 154680384.06 | 27824.12 | **154680384.06** | **27824.12** |
| | | Kakamega Used Lead-Acid Battery Recycling Area | 0.285365 | 34.751255 | Lead | 266063.74 | 586.84 | **266063.74** | **586.84** |
| | | Tononoka Jua Kali Artisans | -4.051008 | 39.668785 | Lead | 65305.82 | 23.29 | **65305.82** | **23.29** |
| | | Gakoromone scrap metal recycling | 0.04626 | 37.6558 | Lead | 109116.73 | 3479.17 | **109116.73** | **3479.17** |
| | | Bangladesh Slums | -4.01162 | 39.633734 | Lead | 50955.20 | 17.23 | **50955.20** | **17.23** |
| | | Mwea (Ngurumbani) scraps metal recyclers | -0.681101 | 37.3583694 | Lead | 1504.21 | 111.90 | **1504.21** | **111.90** |
| | | Kerugoya dumpsite | -0.501764 | 37.284884 | Lead | 88352.13 | 290.45 | **88352.13** | **290.45** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Kapsabet Informal ULAB Recycling Operation | 0.20079 | 35.095613 3 | Lead | 7703.95 | 43.29 | **7703.95** | **43.29** |
| | | Nyeri dumpsite | -0.43139 | 36.962242 3 | Lead | 641.33 | 12.70 | **641.33** | **12.70** |
| | | Kamkunji Blacksmith | 1.283333 | 36.81 6667 | Lead | 1714.13 | 0.27 | **1714.13** | **0.27** |
| | | Owino Uhuru Slum | -4.00772 | 39.61 576 | Lead | 152134.85 | 87.67 | **152134.85** | **87.67** |
| | | Hilton/Gioto dumpsite | -0.26882 | 36.04 817 | Lead | 3994.43 | 10.08 | **3994.43** | **10.08** |
| | | Kariobangi Light Industries | -1.26032 | 36.87 986 | Lead | 488105.58 | 69.60 | **488105.58** | **69.60** |

The national consultant's recommendation is to establish well contained and managed landfill and remediate Dandora. This is well supported by the findings from the calculations. The scores suggest that Kayole Informal ULAB Recycling Area and AP Lead Acid Battery Recycling Company should also be prioritised to reduce the risk from lead pollution.

*Figure 9. Showing the risk and vulnerability site scores for 32 sites. Three (circled) are clearly much higher scoring than the rest.*



# Annex 9. Ethiopia Results of Risk and Vulnerability Calculations

Data was collected for 35 DDT stores. Ethiopia used the earliest iteration of the calculator. At that early stage we were using $Log_{10}$ of the results of the calculations to provide final scores (note we have used antilogs of these scores in order to compare with the results of other countries in the results section of the main document). This had the effect of grouping results into fewer categories and compressing the differences between them. Seventeen of the sites scored most highly for both human health and environment. These stores are largely under the control of the Ministry of Health in relation to mosquito control operations and strongly imply a need to improve the management of DDT stocks and the risks associated with them.

*Table 9 showing results for sites in Ethiopia*

| Site Name | Relative risk to human health | Relative risk to environment | Latitude (North), X | Longitude (East), Y |
|---|---|---|---|---|
| Ameya town | 9 | 6 | 7.106 | 36.681 |
| Arbaminch HC | 8 | 6 | 6.035 | 37.561 |
| Bench Maji ZHS | 9 | 6 | 7 | 35.58333056 |
| Kindokoysha HC | 9 | 4 | 6.8528083 | 37.76096944 |
| Sawla | 9 | 6 | 6.2967667 | 36.88568028 |
| Aby Adi | 7 | 5 | 13.6216667 | 39.00138889 |
| Alamata | 6 | 4 | 12°25'10.81"N | 39°33'13.24"E |
| Dewhan | 9 | 6 | 14°32'47.06"N | 39°26'19.43"E |
| Edaga Arbi | 9 | 6 | 14.0383333 | 39.0675 |
| Endabaguna | 7 | 6 | 13.9513889 | 38.18638889 |
| Abergele | 9 | 5 | 13°5'44.63"N | 38° 56'50.48"E |
| Debark WoHo Store | 9 | 6 | 13°09'10" N | 37°53'56" E |
| Durbetie HC | 9 | 6 | 10.7070667 | 37.35103611 |
| Jabi Tehnan | 9 | 5 | 322122 | 1180244 |
| North Wollo ZH Dpt. | 8 | 6 | 565052 | 1307849 |
| Boke | 7 | 6 | 6.25 | 38.74972222 |
| Guba Koricha | 9 | 6 | 8.8333306 | 40.325 |
| Habro | 8 | 4 | 8.6666389 | 41.33333333 |
| Obera HC store | 9 | 6 | 9.525407 | 37.0404487 |
| S/W Shewa ZH Store | 7 | 4 | 8° 32'17.96"N | 37°58'23.38"E |
| Aysha HS | 6 | 4 | 10.6527306 | 42.61112222 |
| Jgjiga city RHS | 9 | 6 | 9.355 | 36.802 |
| Amibara /Bertal/ | 6 | 4 | 9.286132 | 40.218048 |
| Semera Regional lab 1 | 9 | 6 | 11.79644 | 41.004442 |
| Semera Regional lab 2 | 9 | 6 | 11.795935 | 41.00529 |
| Assosa zone | 9 | 6 | 10.063129 | 34.566037 |
| Dibati | 7 | 4 | 10.778163 | 36.268027 |
| Hamasha | 8 | 6 | 10.317762 | 34.638511 |
| Pawi | 9 | 6 | 11°16'32.74"N | 36°23'9.09"E |
| Wombera | 6 | 4 | 10.625882 | 35.666361 |
| Gambela Town | 9 | 6 | 8° 14.49.88" N | 34° 35.29.75"E |

| | | | | |
|---|---|---|---|---|
| Itang | 6 | 4 | 8.194 | 34.268 |
| Punyido | 6 | 4 | 8.0845806 | 34.37239444 |
| Harari Regional HB Store B | 9 | 6 | 9.3992278 | 42.12795 |
| DD Sabian Hospital Store | 9 | 6 | 9°36'3.15"N | 41°51'0.51"E |

## Annex 10. Gabon results of risk and vulnerability calculations

Seven sites were identified with PCBs. The site in Libreville was of particular concern. The Gabon team had difficulties accessing suitable data to run the R&V calculations. They ran calculations for one site, Décharge Mindoubé, which is a tyre storage and burning site that has lead contamination. It scored 10214.31 for health risk and 15.84 for environmental risk. While this is modest compared to sites in other countries, it still represents a risk to health for people living in close proximity. The team also used the calculator to assess three market gardening sites of fairly limited scale (7.0 ha, 1.3 ha and 2.7 ha) where pesticides paraquat and lambda cyhalothrin were in use and another rubber cultivation site using glyphosate. Score ranged from 7.68 to 90.75 for human health and scored less than 1 for environmental risk. This is an experimental use of the calculator and it would be interesting to explore its use on a larger scale and to collect empirical data alongside it.

## Annex 11. Senegal Results of Risk and Vulnerability Calculations

There were two sites in particular which have extraordinarily high risk scores. These were a pesticide store containing chlorpyrifos, belonging to the DPV (Senegal's Plant Protection Services) and a group of garages highly contaminated with lead. Both sites are located in densely populated areas in Dakar and they merit urgent action to reduce the risk to local residents. The scores for remaining sites, without these two highest scoring ones, are shown in the figure below. By segregating the sites by type of pollutant the graph shows that the highest scoring remaining sites are contaminated with lead. The risk scores are high and there seems to be a common problem here of lead contamination of workshops and garages where lead batteries are being broken down. The majority of the highest risk sites are located in highly populated urban Dakar, but also in Thies and St Louis. These results would justify concerted action to address the lead pollution problem and to consider ways to prevent it.

*Table 10 showing results for sites in Senegal*

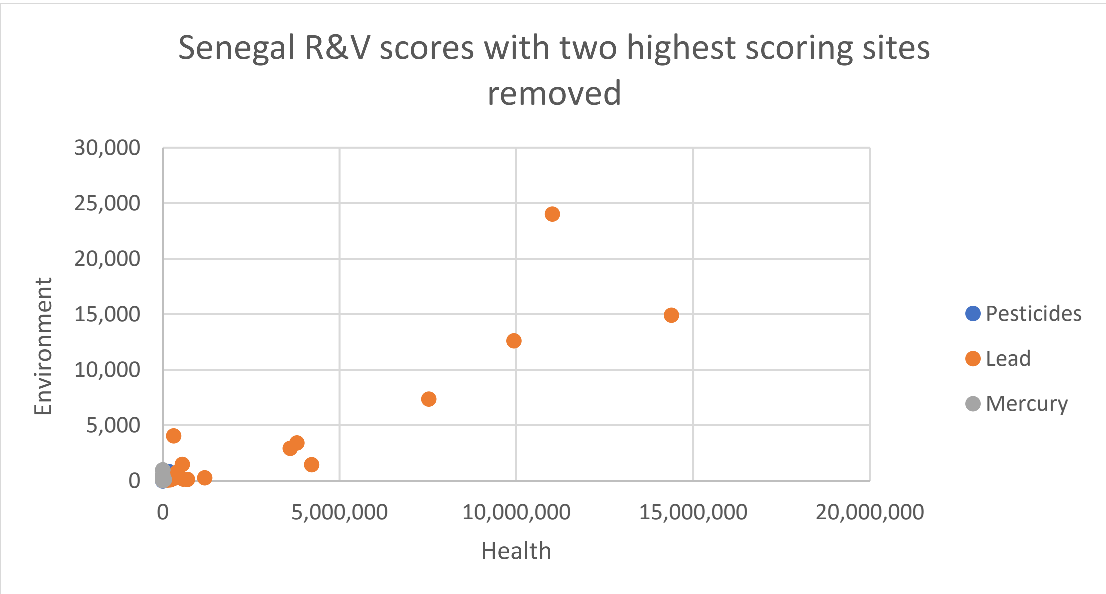
| Site name | Chemical | Relative risk to human health, by chemical | Relative risk to environment, by chemical | Total site score for relative risk to human health | Total site score for relative risk to environment |
|---|---|---|---|---|---|
| **Pesticide storage site of the Directorate of Plant Protection (DPV) Dakar** | **Chlorpyrifos** | **991 485 290.65** | **709,478.40** | **991 485 290.65** | **709,478.40** |
| Pesticide pollution from SDDR store in Diourbel | Aldrin | 131,872.23 | 146.08 | | |
| | Endosulfan | 61,183.07 | 86.9 | **193055.3** | **232.98** |
| Pesticide storage site of the Regional Directorate of Rural Development, Diourbel | DDT | 70347.74059 | 304.44 | **70347.74** | **304.44** |

| | | | | | |
|---|---|---|---|---|---|
| Pesticide pollution from SDDR Mbaké store, Diourbel | Aldrin | 5540.76 | 40.28 | | |
| | Chlordane | 7569.28 | 21.12 | | |
| | DDT | 1188.43 | 4.72 | | |
| | Endosulfan | 479.45 | 5.52 | **14777.92** | **71.64** |
| Storage base of phytosanitay products for DPV of Sokone, Fatick | Dicofol | 240.4 | 0.99 | | |
| | Dieldrin | 82.32 | 0.07 | **322.72** | **1.06** |
| Agricultural Warning Base (BAA) of Ogo / Matam region | Dieldrin | 13,407.86 | 38.42 | **13,407.86** | **38.42** |
| Pollution from Pesticide storage facility at Saint-Louis airport | Dieldrin | 26,391.59 | 87 | | |
| | Fenthion | 21032.65 | 98.94 | **47,424.24** | **185.94** |
| DPV (ST Louis) | Dieldrin | 4940.38 | 17.4 | | |
| | Fenthion | 154,438.16 | 780.68 | | |
| | Chlorpyrifos | 6816.23 | 71.4 | **166,194.77** | **869.48** |
| Pesticide storafge near Ziguinchor Airport | Dieldrin | 63.1 | 0.18 | | |
| | Dicofol | 49.26 | 0.22 | | |
| | Fenthion | 6224.25 | 29.95 | **6336.62** | **30.35** |
| Lead pollution at Reubeuss battery repair and charging workshop, Dakar | Lead | 6704969.7 | 11,668.09 | **6704969.7** | **11,668.09** |
| Lead pollution by Credit Foncier Garage, Dakar | Lead | 233898.76 | 104.79 | **233898.76** | **104.79** |
| Lead pollution at Rue Armand Mangrand battery charging and repair site, Dakar | Lead | 5122085.5 | 2102.5 | **5122085.5** | **2102.5** |
| Mamadou Ndao workshop, storage and sale of batteries, Dakar | Lead | 3,451,781.04 | 2603.23 | **3,451,781.04** | **2603.23** |
| Lead pollution by vehicle repair shop on Rue Felix Eboué, Dakar | Lead | 560157.45 | 423.17 | **560157.45** | **423.17** |
| Mechanical repair garage for vehicles in the Stade Iba-Mar-Diop / RTS1 Dakar | Lead | 3,542,755.66 | 1459.86 | **3,542,755.66** | **1459.86** |
| **Lead pollution by groups of Garages, Dakar** | **Lead** | **309992387** | **2439.92** | **309992387** | **2439.92** |
| Lead pollution from Motor vehicle garages in Parc Ferraille Grand Yoff Bignona, Dakar | Lead | 582086.19 | 182.1 | **582086.19** | **182.1** |
| Lead pollution from mechanical garage at Beno Yoof, Dakar | Lead | 398,118.52 | 771.68 | **398,118.52** | **771.68** |
| Lead pollution at Aly Ndiaye Garage, Dakar | Lead | 105331.52 | 111.02 | **105331.52** | **111.02** |
| Lead pollution from motor vehicle garage, Damel Mixta Kambyeu, Dakar | Lead | 205,123.07 | 100.34 | **205,123.07** | **100.34** |
| Iron Recovery and Scrapyard at Patte d'Oie Damel, Dakar | Lead | 325083.56 | 269.31 | **325083.56** | **269.31** |
| Lead pollution from manufacture of utensils at Technopole, Cambérène, Dakar | Lead | 133663.71 | 91.2 | **133663.71** | **91.2** |
| Lead pollution by vehicle repair garage in Cité Bissap (HLM), Dakar | Lead | 277,635.42 | 245.79 | **277,635.42** | **245.79** |
| Vehicle repair and dismantling workshop at Bolo Dalifort, Dakar | Lead | 3,605,463.85 | 2936.64 | **3,605,463.85** | **2936.64** |
| Lead pollution by Pikine Icotaf vehicle repair garage, Dakar | Lead | 699,920.07 | 145.93 | **699,920.07** | **145.93** |
| Vehicle repair and battery recycling garage Guinaw rail sud (Alla Yana), Dakar | Lead | 1,187,549.57 | 293.66 | **1,187,549.57** | **293.66** |
| Lead pollution by Mechanical garage in Thiaroye Poste, Dakar | Lead | 4,213,721.01 | 1472.5 | **4,213,721.01** | **1472.5** |
| Former battery recycling site (Lunch service) | Lead | 368412.7 | 459.27 | **368412.7** | **459.27** |

| | | | | | |
|---|---|---|---|---|---|
| Lead pollution from Truck parking garage, Malians Mbao, Dakar | Lead | 347,800.45 | 457.31 | **347,800.45** | **457.31** |
| Lead Pollution at Bassirou Samb de Bargny battery repair and dismantling workshop, Dakar | Lead | 554,479.78 | 1490.36 | **554,479.78** | **1490.36** |
| Lead recycling and processing plant, Gravita, Sebikhotane, Dakar | Lead | 304,606.53 | 4047.24 | **304,606.53** | **4047.24** |
| Lead pollution from the ULAB Repair and charging workshop, Dakha Camara | Lead | 185,799.77 | 250.85 | **185,799.77** | **250.85** |
| Lead pollution from a garage in Adama Gaye, Diourbel | Lead | 28009.73 | 131.2 | **28009.73** | **131.2** |
| Lead pollution from battery repair and charging workshop, Touba, Diourbel | Lead | 218,781.07 | 107.69 | **218,781.07** | **107.69** |
| Lead pollution from Car Mechanic at Amadou Ndiaye Sokone, Fatick | Lead | 11456.49 | 76.6 | **11456.49** | **76.6** |
| Lead pollution from Mechanical welding workshop at Ablaye - Balacos, Saint Louis | Lead | 11,018,148.43 | 24033.97 | **11,018,148.43** | **24033.97** |
| Thiès bus station dismantling and battery repair site | Lead | 14384328.44 | 14930.58 | **14384328.44** | **14930.58** |
| Lead pollution from Cheikhou Mbaye Battery Repair Shop, Thiès | Lead | 171,951.02 | 324.38 | **171,951.02** | **324.38** |
| Lead pollution from battery charging and repair shops in Thiès | Lead | 3798241.48 | 3440.43 | **3798241.48** | **3440.43** |
| Lead pollution by Garage and battery repâir in Thies | Lead | 7,521,632.62 | 7375.23 | **7,521,632.62** | **7375.23** |
| Lead pollution at Badara Dieng thies battery Repair Workshop, Thies | Lead | 9931213.63 | 12605.93 | **9931213.63** | **12605.93** |
| Artisanal and small-scale gold mining in Thiabédji, kédougou | Mercury methyl | 2674.9 | 310.44 | **2674.9** | **310.44** |
| Artisanal and small scale gold mining in Tinkoto, kédougou | Mercury methyl | 4907.29 | 184.98 | **4907.29** | **184.98** |
| Artisanal and small scale gold mining in Tomboronkoto, kédougou | Mercury methyl | 4464.25 | 340.79 | **4464.25** | **340.79** |
| Bantaco Mercury Concentration and Amalgamation Site, Kedougou | Mercury methyl | 281.38 | 192.23 | **281.38** | **192.23** |
| Artisanal and small-scale gold mining in Sansamba, Kédougou | Mercury methyl | 3130.06 | 1005.43 | **3130.06** | **1005.43** |
| Artisanal and small-scall gold mining in Baniomba, Kedougou | Mercury methyl | 1210.94 | 357 | **1210.94** | **357** |
| Artisanal and small scale gold mining in Laminia, kédougou | Mercury methyl | 4364.78 | 356.38 | **4364.78** | **356.38** |
| Artisanal and small scale gold mining in Samécouta, kédougou | Mercury methyl | 2948.41 | 186.15 | **2948.41** | **186.15** |
| Artisanal and small scale gold mining in Lafia, kédougou | Mercury methyl | 2766.14 | 421.9 | **2766.14** | **421.9** |
| Artisanal and small scale gold mining in Ngari, kédougou | Mercury methyl | 692.78 | 93.06 | **692.78** | **93.06** |
| Artisanal and small scale gold mining in Mako, kédougou | Mercury methyl | 5300.48 | 52.31 | **5300.48** | **52.31** |
| Artisanal and small scale gold mining in Dalakoye, kédougou | Mercury methyl | 123.62 | 52.31 | **123.62** | **52.31** |
| Artisanal and small scale gold mining at Kérekonko, kédougou | Mercury methyl | 166.25 | 89.66 | **166.25** | **89.66** |
| Artisanal and small scale gold mining in Kanoumering, kédougou | Mercury methyl | 1,497.95 | 89.66 | **1,497.95** | **89.66** |
| Artisanal and small scale gold mining in Massa Massa, kédougou | Mercury methyl | 1584.03 | 459.08 | **1584.03** | **459.08** |
| Artisanal and small scale gold mining at Mandacoly, kédougou | Mercury methyl | 1229.78 | 110.49 | **1229.78** | **110.49** |
| Artisanal and small-scale gold mining in Moussala, Kédougou | Mercury methyl | 1416.6 | 565.07 | **1416.6** | **565.07** |
| Artisanal and small scale gold mining in Guémédji, kédougou | Mercury methyl | 4010.9 | 967.45 | **4010.9** | **967.45** |

| | | | | | |
|---|---|---|---|---|---|
| Artisanal and small scale gold mining in Gomba, kédougou | Mercury metal | 45933.46 | 111.04 | 45933.46 | 111.04 |
| Artisanal and small scale gold mining in Baitilaye, kédougou | Mercury metal | 2511.75 | 125.09 | 2511.75 | 125.09 |
| Artisanal and small-scale gold mining at Kolia, Kédougou | Mercury metal | 1397.25 | 370.66 | 1397.25 | 370.66 |
| Mercury pollution in Wanssangara Mining Site, Kédougou | Mercury metal | 675.13 | 64.75 | 675.13 | 64.75 |
| Artisanal and small-scale gold mining at Daloto, Kédougou | Mercury metal | 662.58 | 62.25 | 662.58 | 62.25 |
| Artisanal gold mining at Madina Baffé, Kedougou | Mercury metal | 1051.55 | 146.74 | 1051.55 | 146.74 |
| Mercury pollution in Khossanto, Kédougou | Mercury metal | 9047.64 | 192.39 | 9047.64 | 192.39 |
| Artisanal and small scale gold mining site iat Niamaya, kédougou | Mercury metal | 449.1 | 26.52 | 449.1 | 26.52 |
| Mercury pollution in Diakhaling, Kédougou | Mercury metal | 1190.86 | 27.86 | 1190.86 | 27.86 |
| Artisanal gold mining in Missira Sirimana, Kédougou | Mercury metal | 940.94 | 60.93 | 940.94 | 60.93 |
| Artisanal and small-scale gold mining at Balakonto, Kédougou | Mercury metal | 1012.53 | 53.58 | 1012.53 | 53.58 |
| Artisanal and small-scale gold mining at Nourang, Kédougou | Mercury metal | 1200.94 | 37.68 | 1200.94 | 37.68 |
| Mercury pollution in artisanal gold mine in Kharaheina, Kédougou | Mercury metal | 481.65 | 127.53 | 481.65 | 127.53 |
| Mercury pollution in Thiankoum Banssan, Kédougou | Mercury metal | 505.75 | 249.68 | 505.75 | 249.68 |
| Artisanal and small scale gold mining in Tenkoto, kédougou | Mercury metal | 1312.76 | 81.06 | 1312.76 | 81.06 |

*Figure 10. R&V Scores for sites in Senegal with the two highest scoring sites removed*



# Annex 12. Zambia Results of Risk and Vulnerability Calculations

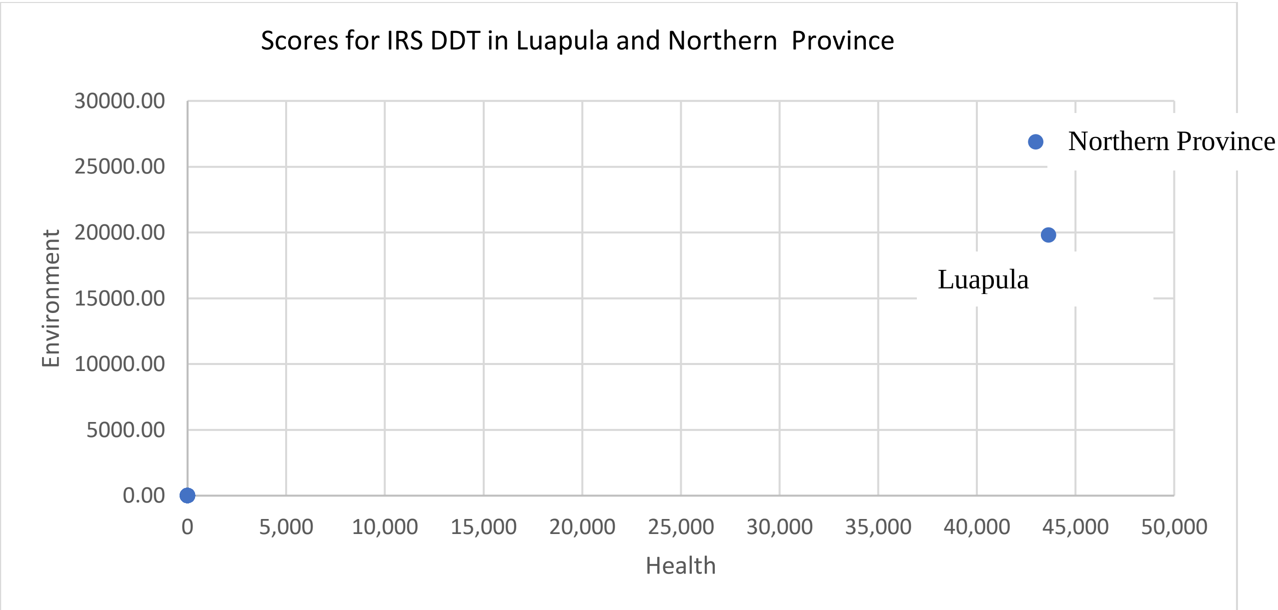
Poisoning data for 2017 from the Ministry of health indicates that pesticides are the primary cause and many of the incidents are of accidental exposure of children and self-harm. A number of other important sources of chemical exposure were identified that are, unfortunately, unsuitable for use in the R&V calculator. These include municipal waste, food residues, discarded pesticide containers, indoor air pollutants and mercury in cosmetics.

The international consultant supported calculations on a rather experimental use of the calculator for indoor residual spraying (IRS) of DDT as well as a large and complex site at Kabwe which are shared here. Data was gathered for four additional sites but the calculations / results have not been shared with the international consultant or included in the vulnerability report.

Indoor residual spraying of DDT

We did not have information about spray operatives so they were left out of the calculations. For families in IRS houses we assumed that the average household contained six persons and their level of exposure is equivalent to the exposure of someone working in a (very small) pesticide store with very poorly contained chemicals. We calculated the average amount of DDT sprayed in each household as 173.37g. We then calculated the score for each household and multiplied it by the number of households. The final scores and graph showing that the health risk score is similar in both provinces, but the environmental risk is somewhat higher in the Northern Province.

*Figure 11. R&V Scores for IRS DDT in Luapula and Northern Province*




Calculating site scores for Kabwe Mine

Kabwe is a very extensive site with heavy lead contamination and residential areas on the perimeter. Soil testing found quite different levels of lead contamination in different parts of the site. For this reason, the site was split into three with different risk score calculations in each, which were then summed. We were careful to calculate the surrounding population based only on the perimeter of the site that was not adjoining either of the other two sections of the site. The final risk score for health was 12876631.34 and the risk score for environment was 14759.2. These are high scores when compared with sites in other countries and would justify further action.

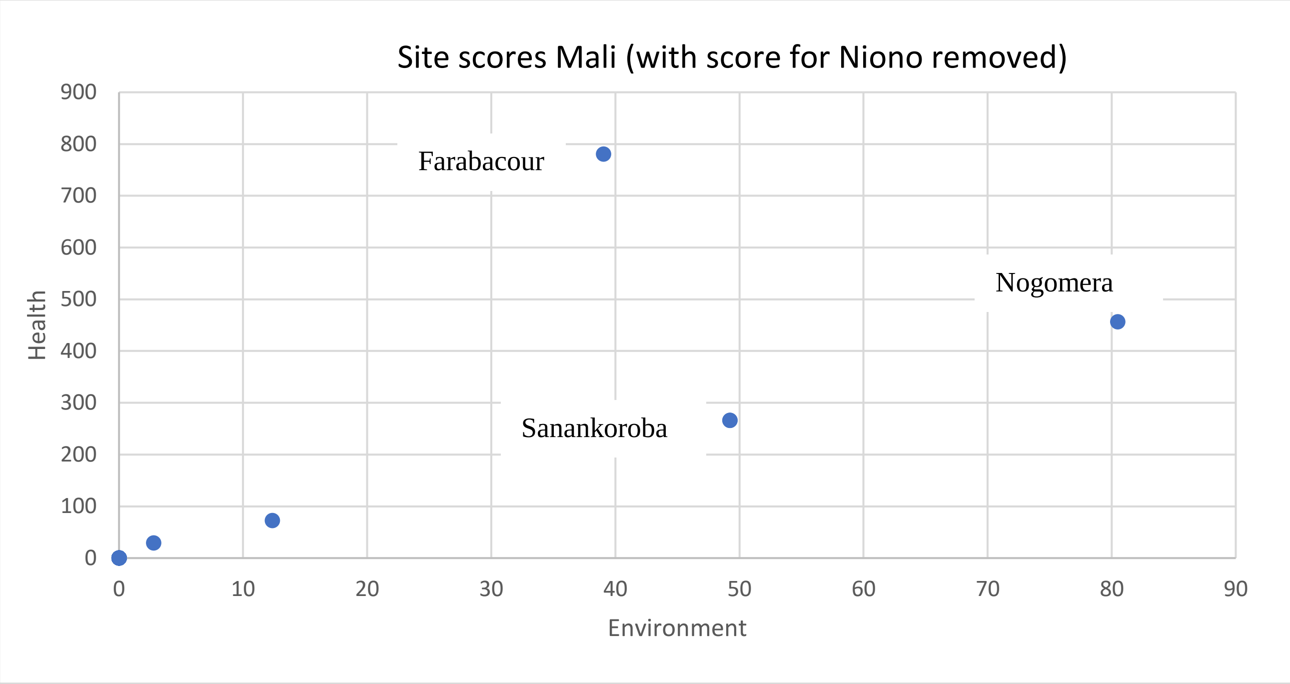
## Annex 13. Mali Results of Risk and Vulnerability Calculations

The national consultant in Mali produced extensive reports with valuable information. Because of difficulty accessing the data, they distributed a questionnaire with the support of the relevant national authority, La Direction Nationale de l'Assainissement et du Contrôle de la Pollution et des Nuisances **(DNACPN)**. They were able to access data on some chemical storage sites and to reach some individual pesticides users (centralised data is lacking). The national consultant requested additional chemicals be added to the data sheet in the calculator (cyanide and pendimethrin) which was done.
Data was obtained for six sites with contaminated land. One site at Farabacoura was contaminated with mercury and the others with pesticides. A site a Niono, which is contaminated with parathion, chlorpyrifos and profenofos had very significantly higher scores than the other sites. Based on this limited information this would be the site that should be prioritised for action if the security situation allows. Of the lower scoring sites Nogomera scored highest for risk to environment and Farabacoura for risk to human health.

*Table 11 showing results for sites in Mali*

| Your name | Date | Site name | Latitude | Longitude | Chemical | Relative risk to human health, by chemical | Relative risk to environment, by chemical | Total site score for relative risk to human health | Total site score for relative risk to environment |
|---|---|---|---|---|---|---|---|---|---|
| AKK | 31/03/2021 | Dialakoroba | 7,940173 | 12,253267 | Dieldrin | 13,75 | 1,23 | | |
| | | Dialakoroba | 7,940173 | 12,253267 | Endosulfan | 33,35 | 6,72 | | |
| | | Dialakoroba | 7,940173 | 12,253267 | Cypermethrin | 25,44 | 4,40 | 72,54 | 12,35 |
| AKK | 31/03/2021 | Niono | 5,995682 | 14,251499 | Parathion | 22500,38 | 2236,55 | | |
| | | Niono | 5,995682 | 14,251499 | Chlorpyrifos | 807,80 | 74,91 | | |
| | | Niono | 5,995682 | 14,251499 | Profenofos | 158990,28 | 26208,00 | 182298,46 | 28519,46 |
| AKK | 07/04/2021 | Sanankoroba | 7,935425 | 12,361976 | Parathion | 174,49 | 38,89 | | |
| | | Sanankoroba | 7,935425 | 12,361976 | Cypermethrin | 91,56 | 10,35 | 266,05 | 49,24 |
| AKK | 07/04/2021 | Farabacoura | 8,253319 | 11,636481 | Mercury methyl | 780,63 | 39,04 | 780,63 | 39,04 |
| AKK | 07/04/2021 | Niogomera | 10,54916 | 15,103579 | Dieldrin | 273,67 | 29,29 | | |
| | | Niogomera | 10,54916 | 15,103579 | Parathion | 183,03 | 51,20 | 456,70 | 80,49 |
| AKK | 07/04/2021 | Molodo | 6,026481 | 14,236449 | Parathion | 9,70 | 1,55 | | |
| | | Molodo | 6,026481 | 14,236449 | Dieldrin | 19,72 | 1,25 | 29,42 | 2,80 |

*Figure 12. showing scores excluding the highest scoring site at Niono*



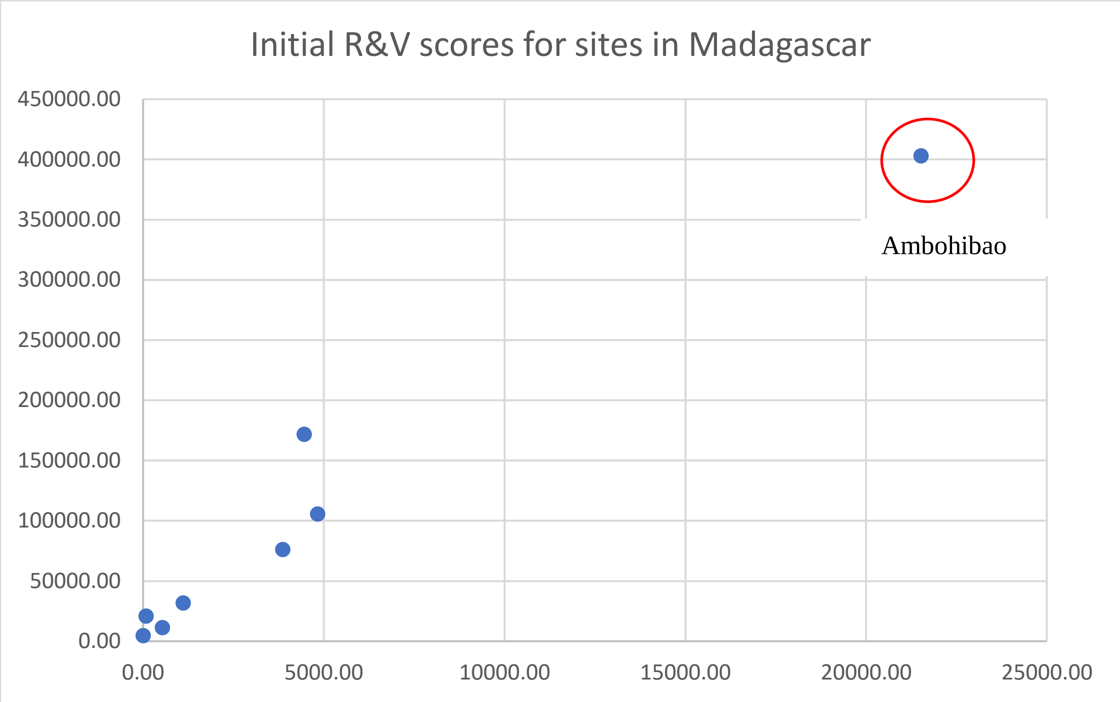
# Annex 14. Madagascar Results of Risk and Vulnerability Calculations

The national consultant completed calculations for eight priority sites in August 2021. However, the national team has recently identified new data and are proceeding with additional analysis.

From the sites that have been considered so far, the site at Ambohibao contaminated with chlorpyrifos scores particularly highly for risk to human health and environment. This finding would support a prioritisation of this site based on the information provided. Other sites also score highly for risk to human health, while the risk scores to environment are more variable. The cause of pollution also ranges over a variety of chemicals including pesticides, PCBs, mercury and lead. The causes of these types of contamination also vary and will merit separate consideration. The chlorpyrifos stock is derived from locust control operations, for example, while the mercury is from artisanal mining.

*Table 12 showing results for sites in Senegal*

| Site name | Latitude | Longitude | Chemical | Relative risk to human health, by chemical | Relative risk to environment, by chemical | Total site score for relative risk to human health | Total site score for relative risk to environment |
|---|---|---|---|---|---|---|---|
| JIRAMA Ambohimanambola | 18.54807 | 47.6 | PCB | 105586.90 | 4826.10 | | |
| | | | | | | **105586.90** | **4826.10** |
| Ambalavato sud Antsirabe | 19.881 | 47.046 | PCB | 76309.80 | 3864.50 | | |
| | | | | | | **76309.80** | **3864.50** |
| Ilafy | 18.855 | 47.565 | PCB | 20954.40 | 81.40 | | |
| | | | | | | **20954.40** | **81.40** |
| Ambohibao | 18.503 | 47.283 | chlorpyrifos | 403135.90 | 21525.10 | | |
| | | | | | | **403135.90** | **21525.10** |
| Andralanitra | 18.54805 | 47.34721 | Lead | 161292.60 | 4374.53 | | |
| | | | Mercury | 10674.74 | 86.16 | | |
| | | | | | | **171967.34** | **4460.68** |
| Ampitambe Ambohibary | | | mercury | 4589.00 | 0.40 | | |
| | | | | | | **4589.00** | **0.40** |
| Imerinafovoany | 18.504 | 47.28 | Profenofos | 11428.50 | 539.90 | | |
| | | | | | | **11428.50** | **539.90** |
| Imerinafovoany (AGRICHEM) | 18.504 | 47.28 | Mancozeb | 31833.90 | 1106.90 | | |
| | | | | | | **31833.90** | **1106.90** |


Initial R&V scores for sites in Madagascar
450000.00
400000.00
350000.00
300000.00
250000.00
200000.00
150000.00
100000.00
50000.00
0.00
0.00
5000.00
10000.00
15000.00
20000.00
25000.00
Ambohibao

# Annex 15. Zimbabwe Results of Risk and Vulnerability Calculations

The Risk and Vulnerability Calculator was used to estimate relative risks to human health and the environment from contaminated sites. 10 such sites were identified and used in the calculator, with nine of them being storage sites for obsolete pesticides, and one being a site where soil has been heavily contaminated with pesticide. From the calculations of relative risks, the sites with the highest risk, in order of decreasing severity were as shown.

a. Gwebi Agricultural College, where 576 $m^2$ of soil is heavily contaminated with fenitrothion
b. Nova Agro Pesticide Company holding at least 4 tonnes of obsolete pesticides, and being in an urban area
c. Coffee Research Institute holding 800 litres of obsolete fenitrothion
d. Matopos Research Centre holding 800 litres of the POP lindane, and 400 litres of EDB
e. Tongaat Hulett holding at least 2.6 tonnes of obsolete pesticides
f. ARDA Maphisa holding 191 litres of the POPs endosulfan and 1,5 tonnes of other obsolete pesticides
g. Wattle Company holding one tonne of obsolete fenvalerate
h. Mlezu Agricultural College holding 31 litres of the POP endosulfan
i. Zimbabwe Sugar Association Experimental Station holding 550 litres of obsolete pesticides
j. Chiredzi Research Station holding 200 litres of obsolete fenitrothion.

The listed sites were not the only ones that are known, but they were the ones with sufficient and usable data. It was therefore recommended that efforts be made to obtain data for the other known contaminated sites so that they can also be included in the calculator and prioritized accordingly.

The site at Gwebi scored very significantly higher than the other sites and, based on the information available, this would be a high priority for risk reduction measures. The site at Nova Agro also scored highly for risk to human health, being located in an urban area. This data and the information about other sites for which data is lacking raises questions about the broader issue of pesticide management.

*Table 12 showing results for sites in Zimbabwe*

| Site name | Latitude | Longitude | Chemical | Relative risk to human health, by chemical | Relative risk to environment, by chemical | Total site score for relative risk to human health | Total site score for relative risk to environment |
|---|---|---|---|---|---|---|---|
| Gwebi Contaminated Site | 17.86667 | 30.68333 | Fenitrothion | 553656.26 | 98610.52 | | |
| | | | | | | **553656.26** | **98610.52** |
| | | | | | | | |
| Mlezu Agric College | -18.91858 | 29.82278 | Endosulfan | 99.33 | 2.08 | | |
| | | | | | | **99.33** | **2.08** |
| ZSA Experimental Station | 20.88361 | 31.62 | Fenitrothion | 44.81 | 23.68 | | |
| | 20.88361 | 31.62 | Chlorpyrifos | 21.77 | 16.24 | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | 66.58 | 39.92 |
| Nova Agro Chemicals, Harare | -17.88567 | 31.0045 | Dimethoate | 16438.46 | 87.51 | | |
| | -17.88567 | 31.0045 | Bromoxynil | 17991.15 | 28.11 | 34459.57 | 148.36 |
| ARDA Maphisa | -21.06833 | 28.49667 | Dimethoate | 29.95 | 32.74 | | |
| ARDA Maphisa | -21.06833 | 28.49667 | Endosulfan | 13.46 | 11.63 | | |
| ARDA Maphisa | -21.06833 | 28.49667 | Alachlor | 29.50 | 5.60 | | |
| ARDA Maphisa | -21.06833 | 28.49667 | Metolachlor | 173.50 | 84.70 | 246.41 | 134.67 |
| Matopos Research | -20.38417 | 28.50806 | Lindane | 86.40 | 58.60 | | |
| Matopos Research | -20.38417 | 28.50806 | Ethylene dibromide | 317.50 | 144.70 | | |
| Matopos Research | -20.38417 | 28.50806 | Endosulfan | 0.92 | 0.26 | | |
| | | | | | | 404.82 | 203.56 |
| Coffee Research | -20.23436 | 32.64806 | Fenitrothion | 1311.70 | 69.40 | | |
| | | | | | | 1311.70 | 69.40 |
| Tongaat Hulett Triangle | -21.0227 | 31.44249 | Chlorpyrifos | 344.36 | 262.67 | | |
| Tongaat Hulett Triangle | -21.0227 | 31.44249 | Fluazifop-P-butyl | 4.35 | 1.76 | 348.71 | 264.43 |
| Chiredzi Research | | | | | | | |
| Chiredzi Research | -21.02024 | 31.57583 | Fenitrothion | 17.65 | 17.76 | | |
| | | | | | | 17.65 | 17.76 |
| Wattle company | -19.65828 | 32.70167 | Fenvalerate | 129.44 | 45.52 | | |
| Wattle company | -19.65828 | 32.70167 | Lindane | 7.25 | 1.13 | | |
| | | | | | | 136.69 | 46.65 |