Independent terminal evaluation

People's Republic of China

Reduction of mercury emissions and promotion of sound chemical management in zinc smelting operations

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Abbreviations

APCD	Air pollution control device
AZSP	Artisanal zinc smelting processes
BAT	Best available techniques
BC	British Columbia
BEP	Best environmental practices
CAT	Conversion and absorption tower
CEO	Chief executive officer
DC	Dust collectors
DCDA	Double conversion double absorption
EPA	Environmental Protection Agency (United States of America)
EPB	Environmental Protection Bureau (provincial authority)
ERPC	Environmental and Resources Protection Committee
ESD	Electrostatic demister
ET	Evaluation team
EZF	Electric zinc furnace
FECO	Foreign Economic Cooperation Office (of Ministry of Environmental Protection, China)
FGS	Flue gas scrubber
FYP	Five-Year Plan
GDP	Gross national product
GEF	Global Environment Facility
Hg^0	Mercury (elemental)
$HgCl_2$	Mercury(II)chloride
Hg_2Cl_2	Mercury(I)chloride or calomel or mercurous chloride
HQ	Headquarters
IEC	International evaluation consultant
ISP	Imperial smelting process
kt	Kilotonne (1,000 tonnes)
L	Litre
M&E	Monitoring and evaluation
MEP	Ministry of Environmental Protection (China)
mg	Milligramme
mio	Million
MRT	Mercury reclaiming tower
MSP	Medium sized project

MTR	Mid-term review
NDRC	National Development and Reform Commission of the People's Republic of China, formerly State Planning Commission and State Development Planning Commission
NEC	National evaluation consultant
PIR	Project implementation report
PMU	Project management unit
ppm	Parts *per* million
QSP	Quick Start Programme (of SAICM)
RMB	Chinese Renminbi
SAICM	Strategic Approach for Chemicals Management
SCSA	Single conversion single absorption tower
SO_2	Sulfur dioxide
t	Ton
TE	Terminal evaluation
ToR(s)	Term(s) of reference
TU	Tsinghua University, Beijing
UNIDO	United Nations Industrial Development Organisation
USTB	University of Science and Technology Beijing
VRZSP	Vertical retort zinc smelting process
WS	Workshop
yr	Year
Zn	Zinc
ZnO	Zinc oxide
ZnS	Zinc sulfide

Glossary of evaluation-related terms

Term	Definition
Baseline	The situation, prior to an intervention, against which progress can be assessed.
Effect	Intended or unintended change due directly or indirectly to an intervention.
Effectiveness	The extent to which the development intervention's objectives were achieved, or are expected to be achieved.
Efficiency	A measure of how economically resources/inputs (funds, expertise, time, etc.) are converted to results.
Impact	Positive and negative, intended and non-intended, directly and indirectly, long term effects produced by a development intervention.
Indicator	Quantitative or qualitative factors that provide a means to measure the changes caused by an intervention.
Lessons learned	Generalizations based on evaluation experiences that abstract from the specific circumstances to broader situations.
Logframe (logical framework approach)	Management tool used to facilitate the planning, implementation and evaluation of an intervention. It involves identifying strategic elements (activities, outputs, outcome, impact) and their causal relationships, indicators, and assumptions that may affect success or failure. Based on RBM (results based management) principles.
Outcome	The likely or achieved (short-term and/or medium-term) effects of an intervention's outputs.
Outputs	The products, capital goods and services which result from an intervention; may also include changes resulting from the intervention which are relevant to the achievement of outcomes.
Relevance	The extent to which the objectives of an intervention are consistent with beneficiaries' requirements, country needs, global priorities and partners' and donor's policies.
Risks	Factors, normally outside the scope of an intervention, which may affect the achievement of an intervention's objectives.
Sustainability	The continuation of benefits from an intervention, after the development assistance has been completed.
Target groups	The specific individuals or organizations for whose benefit an intervention is undertaken.

1 EXECUTIVE SUMMARY

1.1 Introduction

This document contains the report of the Independent Terminal Evaluation (ITE) of the Global Environment Facility (GEF) project entitled ´Reduction of mercury emissions and promotion of sound chemical management in zinc smelting operations´, Project number: GF/CRP/12/001. The project was implemented by UNIDO from 2013 until 2015 and nationally executed by the Ministry of Environmental Protection of the People´s Republic of China, Foreign Economic Cooperation Office (MEP/FECO). The financial resources at the time of the GEF´s Chief Executive Officer (CEO) were USD 990,000 from GEF and USD 4,000,000 as cofinance from host government and host implementing agency, local governments, bilateral sources, academia and the private sector. The agency from the GEF to UNIDO was USD 90,000.

The project was the first project under the Minamata Convention on Mercury that the GEF secretariat approved. The project addressed the goals of reducing mercury emissions and protect human health by:

(i) characterizing mercury emissions from the zinc melting sector in China and globally,

(ii) demonstrating mercury reduction measures through application of best available techniques/best environmental practices (BAT/BEP) in two large scale plants in China under cost-effectiveness parameters and deriving lessons learned from the these experiences, and

(iii) proposing a policy reform to reduce mercury emissions from the zinc smelting industry.

The project was implemented within the approved budget and with one extension at no extra costs to conclude the evaluation of the project.

The independent terminal evaluation for this project was foreseen in the project document as part of the Budgeted Monitoring and Evaluation Plan, with the purpose of conducting a systematic and impartial assessment of the project in line with UNIDO and GEF Evaluation policies. The independent terminal evaluation included an assessment of the relevance, effectiveness, efficiency, sustainability and impact.

The independent terminal evaluation was conducted between October 2015 and April 2016 by Ms. Heidelore Fiedler, international evaluation consultant and Mr. Yu-Feng Li, national consultant. The terminal evaluation consisted of mainly desk evaluations of documentation – technical and financial – provided electronically by the implementing agency either (UNIDO) or the executing agency (MEP/FECO). A field mission to the pilot plants in China by the evaluation team and MEP/FECO was undertaken in November 2015. After the field mission to the two pilot plants in Hunan and Shaanxi provinces, a debriefing was organized by the executing agency at Tsinghua University in Beijing China on 20 November 2015 with the objective to summarize the field mission findings. Since all actors in China were present at the meeting, additional information could be obtained. A second debriefing was organized at UNIDO´s headquarters on 17 March 2016 to present the preliminary findings of the evaluation team and to agree on final steps.

1.2 Key findings and conclusions

The overall rating of the project is satisfactory. At large, a perfect match between the implementing and executing agency in relation to managerial and technical competence was observed, which resulted timely delivery of information in relation to best available techniques in the primary zinc production sector with international importance (before entry into force of the Minamata Convention on Mercury.

1.2.1 Project objectives attainment

The overall rating for ´attainment of the project overall objectives´, *i.e.*, to promote the sound management of chemicals throughout their lifecycle in ways that lead to the minimization of significant adverse effects on human health and the environment and in particular to pilot sound chemicals management and mercury reduction is **satisfactory**. The project included an assessment of the global and the national situation as to zinc production and abatement technologies and did undertake pilot testing at large scale in two plants in China. The desk studies on national and international surveys have been complemented by quantitative measurements of mercury emissions in China. On the basis of two concrete examples, cost effectiveness of different reduction technologies have been applied and budgeted. The results did feed into policy recommendation with some concrete proposals for legislation and needs for modification of sampling/analysis techniques. All targets were met within budget and only a small extension of project duration was necessary (without additional costs to the GEF trust fund).

1.2.1.1 Design

The project design was assessed as **satisfactory**.

The project design addressed the problems associated with zinc smelting and in each of the two pilot plants focussed on the area of most concern, i.e., the highest mercury emissions in the process. The BAT measures were targeted to reduce the largest flow within the plant and thus, reduce the emissions of mercury to the environment and impact on human health. The life cycle approach through sound management of chemicals was applied.

The project´s results framework was formulated along three outcomes: (1) FECO created a coordination and monitoring system for mercury management focusing the zinc smelting sector; (2) BATs/BEPs adopted for cleaner zinc production and (3) FECO developed a mercury management policy to facilitate the application of BATs/BEPs. These outcomes are presented in a work document with clear inter-linkages between them.

A multi-stakeholder approach that included representatives from government, industries and academia were involved and participated in the design and identification of critical problems in zinc smelting operations. Thus, the organizational set-up of the project proved to be adequate and suitable.

Three institutional project partners were sub-contracted by FECO: two zinc smelters, one international expert, and academic institutions from China.

1.2.1.2 Relevance

This project addressed the mercury pollution prevention and control in zinc smelting, which is one of the major concern of the Minamata Convention. It is noteworthy that the Minamata Convention named the 'smelting and roasting processes used in the production of non-ferrous metals´ as a source where mercury emissions should be controlled.

This project provided useful baseline information on the zinc smelting sector in China. With the strong involvement of the two companies, the shift of activities and responsibilities for pollution control to the private sector has been addressed. The linkages between the national and the global situation on zinc production and pollution control make the project relevant for other countries as well. With the findings from this project, initial work during the implementation of the Minamata Convention such as in China´s MIA (mercury initial assessment) will benefit.

The focus of this project falls into both the GEF's focal area and UNIDO's thematic priorities. The project concludes with a list of options for BAT/BEP in the zinc smelting sector in China.

The competence provided by the academic institutions (three universities in China identified and contributing) substantially contributed to the successful implementation of the project and is promising for China´s contribution to the Minamata Convention. .

The relevance is ranked as **highly satisfactory**. Such high ranking was given since the project was developed and approved before the text of the Minamata Convention was agreed demonstrating foresight on future needs. The second and perhaps more important criterion for "HS" ranking is due to the strong participation of the private sector.

1.2.1.3 Effectiveness

The effectiveness of the project was also rating **highly satisfactory**. This ranking includes the effectiveness at national and international levels and all outputs have been achieved:

Information on mercury pollution prevention and control in zinc smelting operation were collected based on national and international knowledge;

BAT/BEP measures were adopted in two zinc smelters and the their efficiencies were assessed;

Mercury management policy recommendations were formulated;

Capacities for the monitoring of mercury (in zinc plants) have been identified and strengthened.

During the project, institutional capacities at national level was built in a synergistic manner to the UNEP-implemented GEF project on initial mercury inventory. Both contributed to the formulation of national implementation plan and the Minamata initial assessment (MIA) of China. The project provides input of a developing country into the BAT/BEP guideline discussions in the Minamata process. Within China, there was no monitoring and evaluation system. On the practical level, capacities for the monitoring of mercury (in zinc plants) have been identified and strengthened at Tsinghua University, University of Science and Technology Beijing and the local Environmental Protection Bureaus (EPBs) as well as at the enterprises. Finally, an economic assessment was concluded.

In technical terms, the outputs achieved with this project included:

- An analysis of the zinc smelting industry in China,
- An analysis of the mercury control mechanisms worldwide,
- The drafting of recommendations for China and the results of the implementation of pilot projects in two sites.
- The project was able to assist Hunan and Shaanxi provinces to establish a mercury emissions inventory, assess the current management scheme and technologies utilized, and enhance capacity in mercury monitoring.
- In addition, the project enabled FECO to understand the zinc smelting industry to a greater extent and the results of the project will be provided to the national council when drafting the next national Five-Year Plan and also contribute to the implementation of another GEF funded mercury project, the Minamata Initial Assessment in China.
- Through the **Hunan pilot plant** experiment, the mercury removal for flue gas mercury removal, smelting slag mercury removal, and waste water mercury removal indicated 97.8%, 42%, and 95.58% efficiency, respectively.
  - After flue gas mercury removal treatment, the content of mercury in the waste acid water was between 0.0015 mg L^{-1} and 0.039 mg L^{-1}, well below the national emission standard, which is 0.05 mg L^{-1}.
  - For the smelting slag mercury removal, a desulfurization tower was constructed.
  - By reducing sulfur dioxide emissions (2,542 tons *per* year), mercury emissions are also reduced at approximately 0.15 tons *per* year.
  - For waste water management, a microcirculation utilization to treat waste water from the acid making process was installed in the zinc fluid bed furnace system. Through the system, all the acid waste water are recycled and amount of water saved is approximately 200,000 tons per year.
- Through the Shaanxi pilot plant project, a reduction of 1,169 kg of atmospheric Hg after installing the desulfurization tower for the volatilization kiln flue gas could be achieved. In addition, approximately 453 kg of Hg would be recovered from the acid slags.

1.2.1.4 *Efficiency*

The rating for efficiency was Satisfactory. A tiered strategy plan was concluded for best available techniques and best environmental practices. This project was not only the first mercury project endorsed by the GEF, it is also "only" a medium-sized project (MSP); thus, relatively little money was provided in the GEF grant but the project leveraged substantial co-finance and initiated practical work by changing production processes at two large-scale primary zinc production plants in China. Such activities typically go beyond pilot projects, MSPs or projects at initial stages of GEF funding.

1.2.2 Sustainability of project

The overall rating of the sustainability of the project is **moderately likely (ML)**; *i.e.*, there are moderate risks that affect this dimension of sustainability. After implementation of just one project – although successful – there is no guarantee that proposed or initiated measures will be implemented and enforced. It will need several years before an experience can be stated.

The sustainability with respect to **financial risks** were rated **moderately likely (ML)**. The project had a pilot character in nature in the sense that it was a large scale demonstration project during a very short timeline (snapshot aspect). It can be expected that within a project under international attention, ad hoc assignments with very good reason were made and the future needs to show the situation under routine conditions. Besides the legal and institutional system, financial arrangements have to be made to account for future investments and administration. Therefore, no statement can be made as to longevity of interventions. During the project implementation, GEF funds and co-finance were handled efficiently and flexible, *e.g.*, reorganization of the co-finance as needs did arise; *i.e.*, when it became obvious that no adequate zinc plant did exist in one of the three proposed regions (it should be noted that at project development state, three provinces were proposed for two pilot demonstrations). The financial details are summarized as follows:

The approved and actual GEF funds were USD 990,000; the promised co-finance (at approval stage) of USD 4,000,000 was exceeded by USD 224,000, resulting in an actual co-finance amount of USD 4,235,000. Notably, the private sector contributed with USD 2,756,000 and academic institutions leveraged USD 441,000. These two together with additional activities by the host government compensated the original higher estimate from the local governments. For details, see section 3.3.1.

The project was highly technical in nature and did not contain elements to investigate the socio-political dimension. The evaluation ranked the sustainability with respect to the **socio-political risks** as **moderately likely (ML)** since during the implementation good cooperation between the project management and the governmental and private sector has been established and no major changes in these structures were observed or identified as a need. The sustainability with respect **environmental risks** were ranked **moderately likely (ML)** due to the pilot character. If fully implemented there are large environmental benefits envisaged since mercury emissions to the environment will be reduced significantly and also the waste management will be improved.

The sustainability with respect to the institutional framework and governance were considered **likely**, *i.e.*, there are no risks affecting this dimension of sustainability.

1.2.3 Monitoring and evaluation

All criteria for monitoring and evaluation, including design, implementation, budgeting, and management were rated **satisfactory**, whereby UNIDO´s "implementation approach" was rated **highly satisfactory** since the project had a clear M&E plan. The M&E plan was strictly followed, i.e., project reports (MEP/FECO to UNIDO) – annually and quarterly; project implementation reviews (UNIDO to GEF) – annually; financial reports – regularly at quarterly basis, and technical reports – according to work plan. Overall, the project M&E plan was found well planned and implemented so that no corrective measures were necessary.

1.3 Conclusions, recommendations, and lessons learned

Conclusion

The overall implementation progress (IP) rating for the project is satisfactory (S). The project has completed all of its activities according to the approved project document including the final independent evaluation by one international and one national consultant. The project reports have been completed by MEP/FECO and her subcontractors.

Key recommendations

This project achieved baseline data for a mercury inventory in the zinc smelting sector through an on-depth evaluation of the national and international situation. Such experiences should be widened-up to include other non-ferrous metal sectors in China and the approach being used as a model for repetition in other countries (with a similar structure of natural resources).

The importance of information exchange and collaboration between UN agencies, government, industry, academia and donors was demonstrated and should be further strengthened.

As a medium-sized project, only pilot testing could be conducted in this project including two smelters in China and one priority reduction technology. In order to get more detailed information on the sound mercury management in the zinc smelters in China, it is highly recommended to start a full-size project as a follow-up and especially assess the long-term feasibility of the proposed and pilot-tested BAT/BEP approaches, which could not be applied due to budget and time limitations.

Other toxic heavy metals may also exist in the zinc ores like lead or cadmium and these should also be considered for a sound management in zinc smelting sectors through a synergistic approach.

Lessons learned

Besides the experiences mentioned above, the co-benefit of parallels and lessons learned from implementation of other multi-lateral environment agreements such as the Stockholm Convention on Persistent Organic Pollutants should be taken into account.

2 EVALUATION OBJECTIVES, METHODOLOGY AND PROCESS

The independent terminal evaluation for this project was foreseen in the project document as part of the Budgeted Monitoring and Evaluation Plan, with the purpose of conducting a systematic and impartial assessment of the project in line with UNIDO and GEF Evaluation policies. The independent terminal evaluation included an assessment of the relevance, effectiveness, efficiency, sustainability and impact of the project.

The independent terminal evaluation was conducted between October 2015 and April 2016 by Ms. Heidelore Fiedler, international evaluation consultant and Mr. Yu-Feng Li, national consultant. The terminal evaluation consisted of mainly desk evaluations of documentation – technical and financial – provided electronically by the implementing agency either (UNIDO) or the executing agency (MEP/FECO). A field mission to the pilot plants in China by the evaluation team and MEP/FECO was undertaken in November 2015. After the field mission to the two pilot plants in Hunan and Shaanxi provinces, a debriefing was organized by the executing agency at Tsinghua University in Beijing China on 20 November 2015 with the objective to summarize the field mission findings. Since all actors in China were present at the meeting, additional information could be obtained. A second debriefing was organized at UNIDO´s headquarters on 17 March 2016 to present the preliminary findings of the evaluation team and to agree on final steps.

This evaluation was guided by the following framework documents:

1. Terms of Reference for the evaluation (see Webpage http://www.unido.org/fileadmin/user_media_upgrade/Resources/Evaluation/CPR_GEFCRP12001_TE_ReductionHgEmissions_TOR_Final_140313.pdf)
2. UNIDO Evaluation Policy (2015).
3. Guidelines for GEF Agencies in Conducting Terminal Evaluation by GEF Independent Evaluation Office (2008)[1]
4. GEF Evaluation and Monitoring Guideline 2010 [2]
5. GEF Evaluation Office Ethical Guidelines (2007) [3]

2.1 General information on the evaluation

The evaluation of the project "´Reduction of mercury emissions and promotion of sound chemical management in zinc smelting operations´, is stipulated in the CEO endorsement document prepared by UNIDO and retrievable from the webpage of the GEF secretariat[4]. Provisions for the undertaking are made in the budget or a total amount of USD 40,000, administered by the executing agency, MEP/FECO.

The terms of reference for the independent terminal evaluation [5] were developed jointly by the UNIDO team at headquarters in Vienna and the executing agency, MEP/FECO, Beijing, Peoples Republic of China. The ToRs have been placed on UNIDO´s Webpage http://www.unido.org/fileadmin/user_media_upgrade/Resources/Evaluation/CPR_GEFCRP12001_TE_ReductionHgEmissions_TOR_Final_140313.pdf with an initial date of May 2015. The international consultant was selected upon application process via the UNIDO recruitment process. The final version of the ToRs for the international consultant is dated September 2015.

The national consultant had received the same specifications to undertake the evaluation on issues on-site in China and especially to evaluate information provided in Chinese language. The national consultant was also responsible for arranging the field visit.

One international consultant and one national consultant were sub-contracted for the independent evaluation; both have not been involved in the implementation of the project. The terms of reference (ToR) for both are included to this report in section "6.1 - Terms of reference", more specifically in section 6.1.1 for the international consultant and in section 6.1.2 for the national consultant. Both form the "evaluation team". The period for the evaluation was from September 2015 until March 2016.

This terminal evaluation report follows the evaluation framework as shown below in Table 1.

All documents available and screened are listed in section 2.3. These include (i) administrative documents in relation to the project application, implementation, procurement, financial and technical reporting and (ii) technical reports in relation to the outputs and deliveries of the project.

Table 1: Evaluation matrix

Evaluation criteria	Document analysis		Interviews	
	Administrative documents (project docs, progress reports, financial reports)	Technical reports, WS reports	Project staff, Minamata int. secretariat	Beneficiaries, consultants
Project design	X		X	
Relevance	X		X	X
Efficiency	X	X	X	X
Effectiveness		X	X	X
Sustainability/monitoring long-term changes	X	X	X	
Project management, monitoring and evaluation	X		X	X
Gender mainstreaming	X	X	X	
Procurement issues	X		X	

All documents available and screened are listed in section 6.5.

Since this project is a medium-sized project, no comments from STAP were requested at the approval stage.

2.2 Scope and objectives

An independent terminal evaluation for this project is foreseen in the project document as part of the Monitoring and Evaluation Plan with the purpose of conducting a systematic and impartial assessment of the project in line with UNIDO and GEF evaluation policies.

The main objective is to assess the performance within the project against the project results framework that is contained in the project document and report the results of the evaluation back to the implementing agency (UNIDO).

2.3 Information sources

The minimum information sources consulted were those specified in the terms of reference for the evaluation of the project. These included documents but also interviews with stakeholders and information of the evaluation team.

At the onset of the evaluation, the evaluation team was provided by the implementing and the executing agency with key documents; in addition, the evaluation teams requested documents and other information from the implementing and executing agencies as well as from other stakeholders of the project. A detailed list of the information sources consulted can be found in the annex in section 6.5 - Documents reviewed.

Upon contracting the international and national evaluation consultants (September 2015), two essential reports were provided by the executing agency (MEP/FECO):

- Project document for the project as approved by the GEF CEO (4)
- Report ´Reduction of Mercury Emissions and Promotion of Sound Chemical Management in Zinc Smelting Operations - Final report´[6]

During the evaluation period, MEP/FECO was requested to provide further information and evidence, which typically was made available to the consultants within a short period of time and in electronic format.

For detailed information as to the information provided by **MEP/FECO**, see section 6.5 - Documents reviewed and especially the section 6.5.2, which contain the documents in relation to the administrative implementation of the project and the technical reports.

UNIDO, the implementing agency was requested to provide documents in relation to the implementation of the project and technical reports (date: 2015-10-12). UNIDO sent the requested documents to the evaluation team within 24 hours. The detailed list of documents consulted can be found in section 6.5 - Documents reviewed, which include the administrative documents and technical reports provided by either the implementing agency or the executing agency.

From the **GEF**: Questionnaire for evaluation sent in November 2015; re-sent in January and February 2016. Finally, GEF responded that she is not commenting for the final evaluation, rather taking the results for consideration of funding in the future.

From **others**: Presentations given in the course of the field visit to the pilot plants and the interviews with the contracted parties were made available to the evaluation team (November 2015). The interim Secretariat of the Minamata Convention filled out a questionnaire prepared by the international consultant. The responses are incorporated into the relevant sections of this terminal evaluation report.

The European Union Reference Document on Best Available Techniques (BAT) for the Non-Ferrous Metals Industries in its final draft (dated October 2014) was consulted as an international source of technical information[7].

2.4 Practical implications

2.4.1 Methodology

This medium-size project did not have a mid-term review; therefore, this evaluation does address all activities that were carried out during the whole period of project implementation. Key questions include the following

- To what extent has the project expected results (outputs and outcomes) by project component were achieved?
- To what extent can the project's results be sustained beyond project closure?

In order to do so, the evaluation team analyzed the substantial documents submitted by UNIDO and MEP/FECO.

A **field mission in China** was undertaken by the evaluation team in November 2015. More specifically, the international evaluation consultant (IEC) met with the national evaluation consultant (NEC) from 15 November to 21 November 2015 and together, the evaluation team (ET) met the main stakeholders of the project as shown below and visited the two pilot sites in Hunan and Shaanxi provinces. At the end of the visit, initial findings were presented to MEP/FECO as well as the scientific technical partners of the project in Beijing on 20 November 2015. The schedule of the mission as well as the most important contacts are available in section 6.

Stakeholders consulted during field mission to China in Beijing:

1. Ministry of Environmental Protection-Foreign Economic Cooperation Office (MEP/FECO)
2. Tsinghua University (TU)
3. Renmin University of China
4. University of Science and Technology Beijing (USTB)

Field visit to pilot plants:

1. Shuikoushan zinc plant (included the participation of the Hunan Environmental Protection Bureau
2. Shangluo zinc plant

The interview of the project manager at UNIDO, the implementing agency, was carried out electronically in February 2016. It shall be noted that the UNIDO project manager responsible for this project had changed jobs in 2015 and was no longer available at UNIDO headquarters. The UNIDO project manager responsible at the onset of the project was interviewed by Skype in October 2015 –before the field mission to China – and electronically in February 2016. He was considered the main project staff for the implementing agency in this evaluation since he left after completion of the technical activities of the project. He also provided further input through a questionnaire in February 2016. The new project manager was readily available to assist in the final evaluation. A physical **meeting** between the international consultant and the implementing agency as held at the UNIDO headquarters on 17 and 18 March 2016. Further details on the schedule is available in section 6.4

During the same mission, the preliminary findings were presented to UNIDO Project management and UNIDO evaluation unit. The visit provided the opportunity to receive feedback, receive further documentary information and undertake a verification exercise.

The majority of documents were made available electronically *per* e-mail exchange.

2.4.2 Limitations encountered

The time initially allocated for the evaluation of the project (four months; September through December 2015) was found to be too short since the international consultant started work only in October 2015 and with the Chinese New Year in early February 2016, the evaluation period stretched over into March 2016.

Inherent to the project´s geographic location, several reports, especially the technical reports from the pilot plants, were available in Chinese language only. Although the international consultant has intermediate knowledge of Chinese, the national consultant, a Chinese national, had to translate key findings into English for use in this evaluation report. Where necessary, translation was provided through the executing agency, MEP/FECO. It was highly appreciated that at the meeting in Beijing (during the evaluation mission), the subcontracted universities were able to present their work in English language and participate in the discussions.

2.4.3 Validity of the findings

The findings, especially in relation to the options and applicability of best available techniques and best environmental practices (BAT/BEP) have been developed and adapted to the Chinese situation. At the time of the project implementation and the terminal evaluation (early 2016 at latest), the BAT/BEP issues had not yet been concluded under the Minamata Convention on Mercury. Therefore, an internationally agreed benchmark did not exist. For this terminal evaluation, the Evaluation Team consulted the European Union "Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries" in its published draft version of November 2014 [7].

The approach from its technical scientific value have been published in peer-reviewed journals and thus, have undergone external valuation.

In this respect, the executing agency, MEP/FECO, undertook desk studies together with national experts to inform itself about BAT/BEP applications in other parts of the world. The executing agency also hired an international consultant to prepare key documents on the present situation of mercury control at international level. The outputs (reports of the international consultant) have been made available by UNIDO and are listed in section 6.5.

A Chinese delegation visited the United States of America and Canada from 21 November 21 to 26 November 2013, for firsthand information on mercury pollution control in the zinc smelting sector under this project. In the USA, the Chinese delegation was received by the Office of International and Tribal Affairs, United States Environmental Protection Agency, in Research Triangle Park, NC. Main issues to discuss were the views and approaches on air pollution prevention and control system including laws, regulations, standards, policies, atmospheric environmental quality management in non-ferrous metal smelting industries, especially zinc smelting industry. In Canada, the delegation visited Teck Corporation in Trail, BC; the world's biggest lead and zinc smelting corporation. During the visit, an informal meeting was organized with people from the Canada EPA and experts on mercury pollution prevention and control experience of laws, technology, economic and management. Chinese delegation also introduced the information with respect to the air mercury pollution prevention, mercury policies, emission standards in non-ferrous metal industry in China, as well as multilateral and bilateral instruments of cooperation in zinc smelting industry.

3 COUNTRY AND PROJECT BACKGROUND

3.1 Country context

The People's Republic of China is located in the eastern part of the Asian continent, on the western Pacific Rim. It is a vast land, covering 9.6 million square kilometers. China is approximately seventeen times the size of France, 1 million square kilometers smaller than all of Europe, and 600,000 square kilometers smaller than Oceania (Australia, New Zealand, and the islands of the south and central Pacific). Additional offshore territory, including territorial waters, special economic areas, and the continental shelf, totals over 3 million square kilometers, bringing China's overall territory to almost 13 million square kilometers.

3.1.1 Overview of the economy

Since 1978, China has maintained a favorable situation in economic development. In 2014, the GDP reached 63,646 billion yuan, an increase of 7.4% in comparison to that of 2013. Of the total GDP, those of the primary, secondary and tertiary industries were 5,833 billion yuan, 27,139 billion yuan and 30,673 billion yuan, respectively. Investment in fixed assets of the whole society was 50,200 billion yuan.

3.1.2 Overview of the environment

Environmental issues in China are plentiful, severely affecting the country's biophysical environment and human health. Rapid industrialization, as well as lax environmental oversight, are main contributors to these problems.

The Chinese government has acknowledged the problems and made various responses, resulting in some improvements. In 2014, China amended its protection laws to help fight pollution and reverse environmental damage in the country. In response to an increasingly problematic air pollution problem, the Chinese government announced a five-year USD 277 billion plan to address the issue. Northern China will receive particular attention, as the government aims to reduce air emissions by 25 percent by 2017, compared with 2012 levels, in those areas where pollution is especially serious.

3.1.3 Overview of institutional development

In recent years, China has paid increasing attention to the prevention and control of mercury pollution. Since the 1990s, China has conducted research on mercury emissions to the atmosphere. It has created numerous primary and secondary laws that contribute to the prevention and control of mercury pollution. Notable amongst these are the 'Law on the Prevention and Control of Atmospheric Pollution' and the 'Cleaner Production Promotion Law of the People's Republic of China' that contribute amongst other things to the control of mercury pollution.

In 2009, the General Office of the State Council issued the 'Guiding Opinion on Strengthening Prevention and Control of Heavy Metal Pollution', to set objectives and provide funding for heavy metal pollution prevention and control.

The Environmental and Resources Protection Committee (ERPC) of the NPC is responsible for developing, reviewing and enacting environmental laws.

Under the State Council, the MEP, the highest administrative body for environmental protection, is responsible for developing environmental policies and programmes. The MEP deals with policy and regulatory matters from standards setting to enforcement, environmental impact assessments, and international conventions.

As a cabinet-level ministry, the MEP can be directly involved in high profile decision making and has the authority to co-ordinate other cabinet-level ministries in order to address environmental problems. Several ministries and agencies under the State Council are involved in environmental management. In particular, the State Development and Reform Commission, the Ministry of Health, the Ministry of industry and Information Technology, and the State Food and Drug Administration have distinct roles in environmental protection associated with infrastructure construction and management (including environmental impact assessment), industrial policy, human health, food and drugs and implementing international agreements related to mercury management.

The mercury working group under FECO/MEP was established on April 1, 2010. It is responsible for conducting research on mercury management, mercury-related policies and technologies; provision of technical support to intergovernmental mercury negotiations; development and implementation of international cooperative projects; preparation for Mercury Convention implementation. After the Chinese government signed the Minamata Convention on Mercury, the group was upgraded to a new division called 'Mercury Convention Implementation Division'.

There are many different industrial associations related to mercury management in China, for example the China National Coal Association, China Petroleum and Chemistry Federation, China Non-ferrous Metals Industrial Association, China Association of Light industry, China Battery Industrial Association and China Medical Devices Association.

3.1.4 Overview of demographic and other data of relevance to the project

The demographics of the People's Republic of China are identified by a large population with a relatively small youth division, which is partially a result of China's one-child policy. The Chinese population reached the billion mark in 1982.

By the end of 2014, the population in Mainland China (not including Hong Kong, Macau and Taiwan) is 1,367,820,000, the largest of any country in the world. According to the 2010 census, 91.51% of the population was Han Chinese, and 8.49% were minorities. China's population growth rate is only 0.47%, ranking 159th in the world.

3.2 Sector-specific issues of concern to the project and important developments during the project implementation period

The project was implemented in a way that a tiered approach was taken, which is also reflected in the final report produced by MEP/FECO, as follows:

1. Overview of the zinc production in China as a desk study including
    a. Description of the smelting processes
    b. Mercury pollution technical control measures
    c. Policy measures to control mercury emission from zinc smelting industries
2. Summary of the zinc production at global level including

a. Global zinc production

b. Mercury pollution and emission control of global zinc industry

c. Management system on mercury pollution prevention in zinc sector in developed countries

d. Gap analysis of China

3. Pilot testing of BAT/BEP measures for emission control in China´s zinc smelters

4. Definition of technical and policy measures in relation to BAT/BEP in China´s zinc industry

The final report is complemented by detailed information in the Annex on

1. Mercury regulatory standards at national level
2. Mercury provincial management measures (Hunan and Shaanxi provinces)
3. Pollution control measures in the pilot smelters

This section summarizes and highlights the most important findings from this project including the pilot testing in the two full-scale plants that participated in this project. Throughout the project and this assessment, the term "pilot" refers to the fact that not all zinc production plants have been investigated and does NOT refer to the scale of these plants. It should be noted that typically "pilot plant" means an installation that mimics the process under investigation but at a scale large than "laboratory scale" but [much] smaller than full-scale commercial operation.

3.2.1 Summary of the zinc reserves, production and consumption at global level

The project established a snapshot on the current situation with respect to global resources of zinc, are displayed in Figure 1. The changes in global zinc production by the world´s largest zinc producing countries are shown in Figure 2. Among the zinc consumers, by far the highest share is in China which accounts for 43%, followed by the USA with 9%.

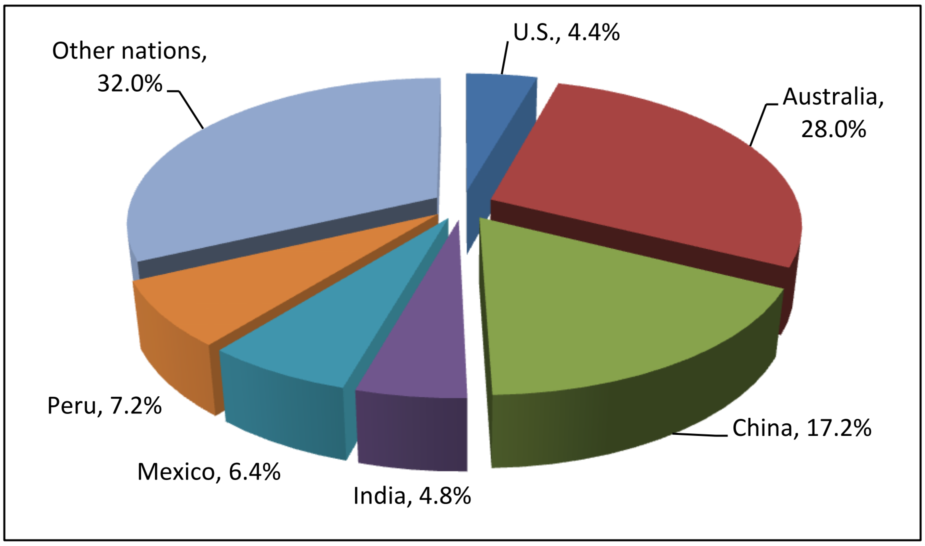

Figure 1: Global zinc reserves

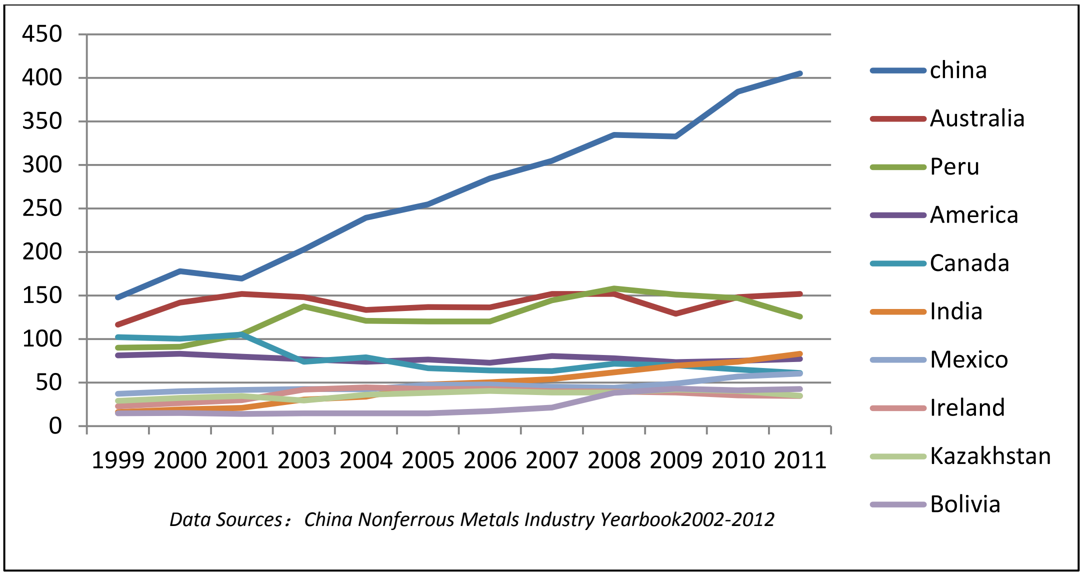

Figure 2: Global zinc production by country

3.2.2 Overview of the zinc production in China as a desk study

3.2.2.1 Scale of zinc production

The zinc production in China increased between the years 2000 and 2010 from 1.96 million ton to 5.21 million ton whereby for both years, the vast majority was primary zinc and the secondary zinc only contributed with 3.6% or 3.4%, respectively (see Table 2). In terms of geographic distribution, ten provinces produce 93.5% of zinc (1.21 million tons) with Hunan province responsible for 23.2% of national production. One of the pilot plants in this project is located in Hunan, the other is located in Shaanxi; the province on third place of national production.

Table 2: Summary of zinc production in China, year 2000 *vs.* year 2010

Sector	2000 (in million tons)	2010 (in million tons)
Zinc production total, of this	1.96	5.21
Primary zinc	1.89	5.03
Recycling (secondary)	0.6697	0.1753

A more detailed picture on production amounts of refined zinc in China is shown in Figure 3.

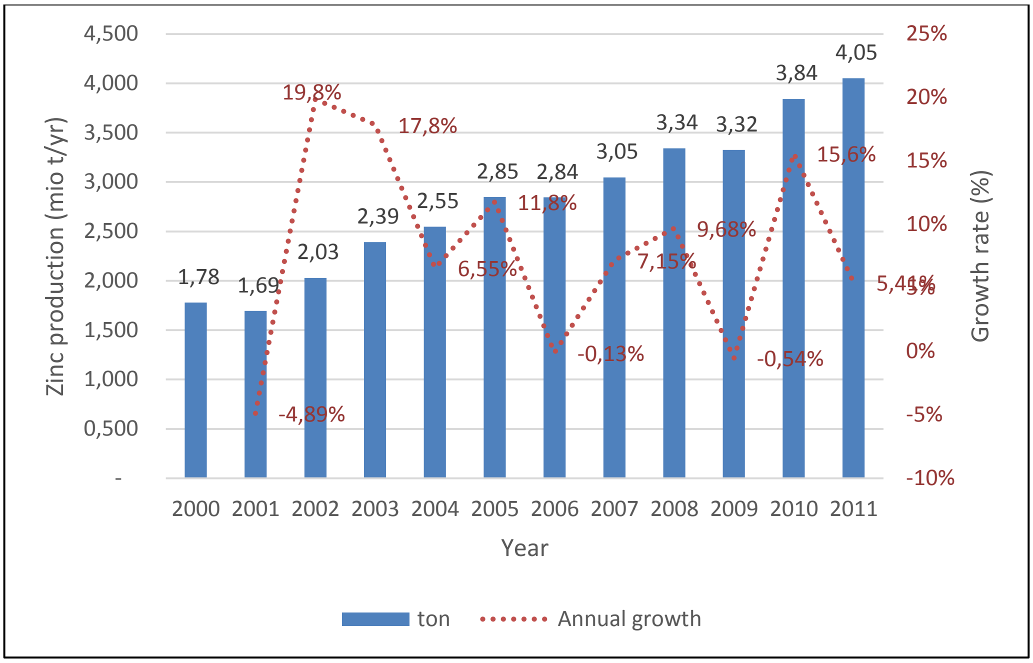

Figure 3: Zinc production in China between 2000 and 2011 (annual resolution)

The national production occurred in more than 100 plants (2010 data); most of them located in the central and southwest of China (see Figure 4). Of these, 17 smelters have an annual capacity above 100,000 t *per* year.

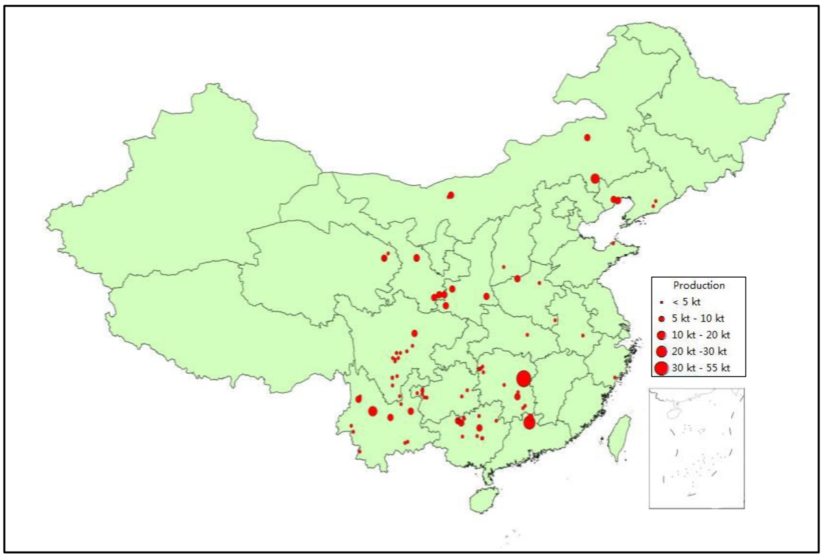

Figure 4: Location and size of zinc smelters in China

3.2.3 Description of the smelting processes

A generic picture of the zinc smelting process as shown in Figure 5 is used for the assessment of BAT and BEP measures and the calculation/estimates in terms of environmental impacts and reduction technologies. Other figures in this report show specific aspects of the processes or the changes made during the pilot testing. Emissions (E) can occur from the four process steps dehydration, roasting, extraction or reclaiming. Typically, air pollution control devices are/shall be installed to reduce emissions to air. The most commonly used are dust collectors to remove coarse or fine particles. For further information, see section 3.2.3.1.

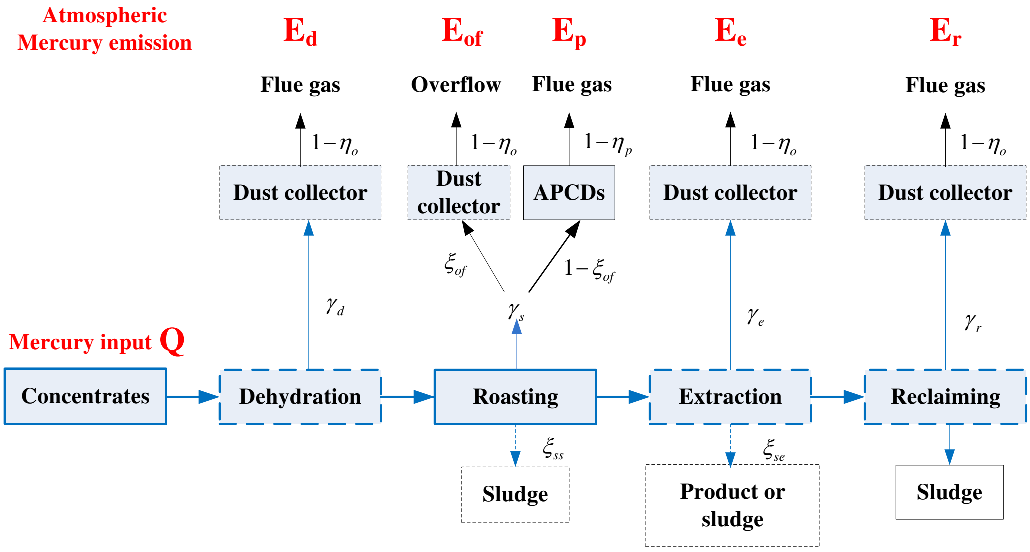

Figure 5: Generic flow chart for zinc smelters

The zinc smelting processes in China can be divided into two broader groups:

(i) Pyrometallurgical process; used to produce 11.3% of the zinc in 2010. Three of the large smelters in China (>100,000 t *per* year) used this technology, and

(ii) Hydrometallurgical process; used to produce 78.7% of the zinc in 2010. Thirteen of the large smelters in China (>100,000 t *per* year) used this technology. One smelters applied direct oxygen pressure leaching (a variant within the hydrometallurgical processes)

A graphical sketch of the two process types is shown in Figure 6.

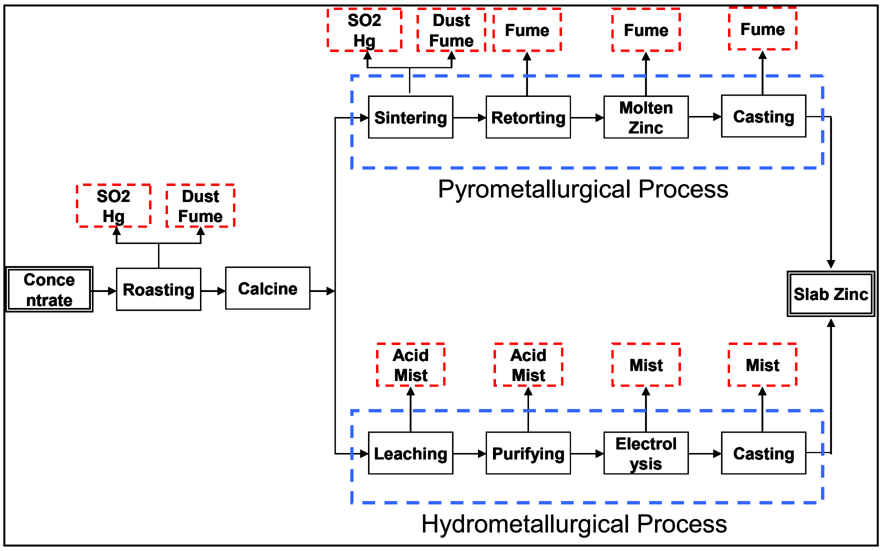

Figure 6: Graphical sketch of the two zinc melting processes used in China

The **pyrometallurgical processes** can further be divided into the

- Imperial smelting process (ISP); 7.1% of total zinc production[a];
- Vertical retort zinc smelting process (VRZSP); 7.9% of total zinc production [a];
- Electric zinc furnace (EZF); 1.3% of total zinc production [a]; and
- Artisanal zinc smelting processes (AZSP); 2.5% of total zinc production [a].

The first two above-mentioned processes are the main pyrometallurgical process used in China. The EZF is only used in small or medium scale smelters and the AZSP has been eliminated in China in recent years.

A graphical sketch of the **hydrometallurgical process** is shown in Figure 7. In the hydrometallurgical process, atmospheric Hg is mainly emitted from the roasting stage. In the leaching, purification and electrolysis stages, an aqueous leaching technique is applied for obtaining zinc (or other metals) metals from their ores. In the leaching, purification and electrolysis stages, refined zinc is produced without a high temperature step in the process. Thus, mercury contained in the roasted materials flows into wastes or liquids. Atmospheric emissions of mercury from these stages are less in comparison to the pyrometallic process.

[a] Reference year 2010

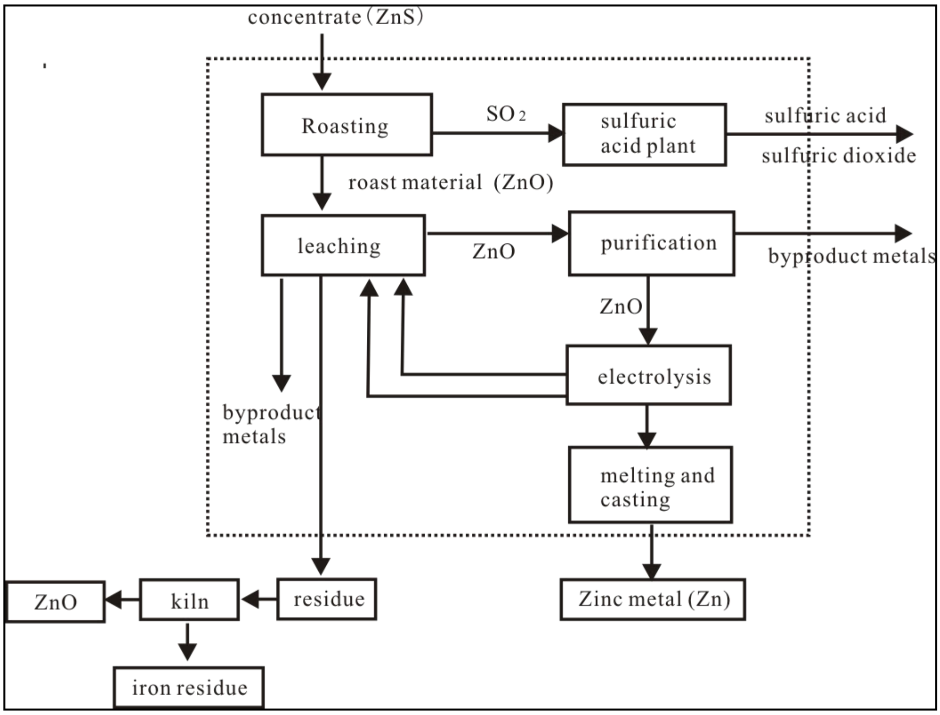

Figure 7: Graphical sketch (detail) of the hydrometallurgical melting process

In brief, zinc concentrates (mainly zinc sulphide, ZnS) are roasted into zinc oxide (ZnO); then the metallic zinc is leached from the ZnO in an acid solution and finally extracted with electrowinning technology. Within the hydrometallurgical zinc production process, releases of mercury to the environment may occur from the following process steps:

1) primary metal roasting,
2) calcine processing,
3) leaching,
4) purification, and
5) electrolysis.

3.2.3.1 Mercury pollution technical control measures

The removal of mercury as far upstream in the zinc process is desirable in order to minimize the chance of mercury entering the final product acid. Various methods have been developed for removing mercury from the gas before it enters the drying tower of the acid plant.

The report from Tsinghua University summarized information obtained from 106 nonferrous metal smelters: Generally, air pollution control devices (APCDs) for primary flue gas in most nonferrous metal smelters consist of dust collectors (DC) including cyclone dust collector, waste heat boiler, electrostatic precipitator and fabric filter (F), flue gas scrubber (FGS), electrostatic demister (ESD), mercury reclaiming tower (MRT), and conversion and absorption tower (CAT). The CAT may be a double conversion double absorption (DCDA) tower or a single conversion single absorption tower (SCSA). Usually, the above APCDs combined into seven types of combinations used in smelters (Table 3).

Table 3: Types of APCDs commonly occurred in non-ferrous metal smelters

APCDs	Type of APCDs combination	Zinc industry	
		Production (kt)	Percentage (%)
DC+FGS+ESD+DCDA	1	3,841	76.3
DC+FGS+ESD+MRT+DCDA	2	508	10.1
DC+FGS+ESD+SCSA	3	69.5	1.38
DC+FGS	4	37.2	0.74
DC	5	172	3.42
FGS	6	1.68	0.03
None	7	275	5.47

Based on the tests performed at the smelters, the efficiency for mercury removal by the various technologies was summarized as follows (Table 4). The technologies are separated into synergistic mercury control devices and dedicated mercury removal devices. The costs for installation of the equipment at the sulfuric acid plant for an assumed 200,000 t of sulfuric acid production are shown in Table 5. The costs were made and presented in Chinese Renminbi (RMB) in units of 10,000 RMB; however, for this terminal evaluation the costs are shown in USD using the RMB-USD currency conversion rate as of 1 July 2014 (1 RMB = 0.1516 USD). No rounding of the numbers was undertaken; therefore, the costs are rough estimates although the high number of significant numbers implies a very high precision.

For the specialized mercury control technologies, only the Boliden Norzink is used at one of the zinc plants in China (none of the pilot plants used it). The Boliden Norzink process was developed in 1972 and is the most popular method for removing mercury from the process gas globally. The Boliden Norzink technology is a continuous scrubbing process for the removal of Hg^0; *i.e.,* oxidation of mercury vapour through addition of mercury(II)chloride ($HgCl_2$) to generate mercury(I)chloride or calomel (mercurous chloride, Hg_2Cl_2).

$$HgCl_2 + Hg^0 \rightarrow Hg_2Cl_2$$

Hg_2Cl_2 is insoluble in water and precipitates out of the solution to the bottom of a conical tank. The product sulfuric acid contains less than 0.5 ppm of mercury and can be produced from a gas that contains up to 150 ppm of mercury.

The clarified solution overflows back to the scrubbing tower pump tank. The collected solids from the bottom are further concentrated, before being discharged to storage drums for sale or further processing. The scrubbing solution maintains a portion of the mercurous chloride collected, which is chlorinated with chlorine gas (Cl_2) to $HgCl_2$ to regenerate the scrubbing solution:

$$Hg_2Cl_2 + Cl_2^0 \rightarrow 2\ HgCl_2$$

A product acid containing less than 0.5 ppm mercury can be produced from a gas containing 150 ppm mercury.

Table 4: Efficiency of mercury removal technologies according to tests in China

	Pollution control devices	Mercury removal efficiency	Number of devices tested
Synergistic mercury control devices	Cyclone dust collector	0.11%	7
	Electrostatic precipitator	2.39%-20.4%	10
	Waste heat boiler	0.64%	7
	Fabric filter	25.2%-56.10%	5
	Flue gas cleaning	17.4%-66.6%	2
	Electrostatic demister	30.3%-32.3%	2
	Single contact and single adsorption	55.4%	1
	Double contact and double adsorption	68.4%-99.7%	7
Dedicated mercury removal technologies	Boliden-Norzink	High concentration of mercury in flue gas: >98% Low concentration of mercury in flue gas: 70%-80%	1
	KI technology	97%	1
	Direct condensation technology	80%-90%	1

Table 5: Costs of installation at the sulfuric acid plant

Project	Cost (USD)			
	Construct-ion work	Equipment	Installat-ion work	Subtotal
Waste heat boiler	255,816	1,710,172	274,227	2,240,215
Waste heat power station	302,005	2,381,301	137,550	2,820,856
Electrostatic precipitator	323,000	1,938,000	484,500	2,745,500
Sulfuric acid purification section	1,095,939	2,457,497	417,058	3,970,494
Sulfuric acid dehydration section	448,163	3,165,206	539,991	4,153,360
Sulfuric acid conversion section	80,750	3,274,542	535,582	3,890,874
The wind turbine room and substation	557,175	1,597,703	214,569	2,369,447
Circulation pump room of sulfuric acid	211,565	577,944	70,479	859,988
Acid storage vault and loading platform	263,051	666,995	50,808	980,854
Comprehensive building of sulfuric acid	261,630	411,890	97,062	770,581
Total	3,799,094	18,181,250	2,821,825	24,802,169

In China and in 2008, the price of industrial quality sulfuric acid was 393 RMB *per* ton, corresponding to approximately 64 USD *per* ton. The real costs to produce one ton of sulfuric acid was estimated to be 263 RMB (corresponding to 43 USD); thus, a net win of 21 USD *per* ton of sulfuric acid. On the other hand, the pure installation cost for additional control equipment (value of equipment plus installation work) is around 124 USD *per* ton of sulfuric acid produced and sold (corresponding to 768 RMB/t). This is about 3-times the profit margin and therefore, the economic assessment concluded that the control of SO_2 is key for the pollution control and since the zinc plants have to comply with the SO_2 limit values, the synergistic removal of SO_2 and mercury has the benefit that no additional costs for the mercury control is necessary.

3.2.3.2 *Policy measures to control mercury emission from zinc smelting industries*

At the onset of the project, some laws and regulations about pollution prevention and management of the zinc smelting industry existed but either were vague or enforcement was low. For example, companies were required to develop contingency plans in case of environmental accidents and undertake regular exercises but the evaluation criteria and frequency of these exercises were not clear. Also, companies were required to periodically monitor the environmental quality of air, water, soil, and the potential hazards, but the specific monitoring criteria including frequency and whether information should be made public had not been stipulated.

China has initially established mercury control standard system in the zinc smelting industry (combined with lead smelters) such as "The specification conditions in zinc and lead industry", "lead, zinc industry emission standards” and“ lead and zinc smelting industrial pollution control technology policy". At the time of the start of the project, these existing mercury control standards still needed to be further strengthened and improved and it should be noted that the vast majority of China's zinc smelting enterprises had not installed dedicated mercury removal equipments. Only one of the 17 large companies installed dedicated mercury removal facilities. Real incentives for innovation and promotion of dedicated mercury removal technologies did not exist.

For the INC-4, China submitted the following information as to mercury control standards[b]. The provisions for the zinc smelting industries were as follows:

1. The currently existing atmospheric thresholds of mercury emission to air

It is mainly by means of implementing the pollutants emission standards in China to control atmospheric mercury emission from coal - fired power plants, none - ferrous metals production facilities, domestic waste incineration, *etc*. The mercury emission standards and thresholds include:

Emission Standard of Pollutants for Lead and Zinc Industry (GB25466-2010), the threshold value is 0.05 mg/m^3, applying to sintering and smelting

2. Mercury releases to water

It is mainly by means of implementing pollutants emission standards to control the mercury releases to water in China. The currently existing mercury release standards and thresholds to water include:

Emission Standard of Pollutants for Lead and Zinc Industry (GB25466-2010), the threshold value is 0.03 mg L^{-1} (aggregated/total mercury) and applied for “general areas”. However, in areas where the land development is high and the environmental carrying capacity becomes weak or where the ecological environment is fragile or where serious environmental problems caused by pollution are expected, the lower limit of 0.01 mg L^{-1} is in place.

3. Mercury releases to land: There is no such information and data available in China.

In a nutshell: The “lead and zinc industry standard conditions” were originally released in 2007 by the National Development and Reform Commission and named "lead and zinc industry access". This was replaced in 2015 by the Ministry of Industry and Information Technology as the "lead and zinc industry standard conditions" (the word “access” was replaced by “condition”). In the "standard

[b] http://www.unep.org/hazardoussubstances/Portals/9/Mercury/Documents/INC5/Submissions/China.pdf

conditions", the related provisions with respect to mercury releases from the zinc smelting industry are as follows:

(1) The requirements on technologies with respect to the sulfuric acid plant —making synergistic effects on mercury reduction

As for the newly-built zinc smelter program, roasting of the zinc sulphide concentrate must apply technologies with high sulphur utilization rate and the roasting process must be equipped with qualified exhaust control equipment. The area of the single boiling roaster furnace must be larger than 100 square meter and the plant must have a double conversion double absorption system.

To strengthen the management and utilization of recycling for zinc as a secondary resource, advanced technology and equipment must be used including requirements on buildings and renovation (modernization). In the pyrometallurgical processes kilns must have slag recycling facilities, waste heat recovery and utilization systems as well as exhaust gas desulfurization systems. Special equipment should be built/presented to handle fluorine and chlorine.

The sulfuric acid plant is an option to reduce mercury, and its efficiency is nearly 80%. Thus, when strict requirements are made for the acid plant at approval/commissioning stage, synergistic positive effects on mercury reduction can be obtained.

(2) The requirements on exhaust gas purification —reducing mercury emission to air

The existing enterprises should be equipped with exhaust gas desulfurization and waste heat recovery systems. The process using the pyrometallurgical processes must be conducted under wind-tight conditions and prevent the escape of harmful gases or dust from the process. Exhaust gas purification system, alarming system and emergency treatment devices must be established. When the hydrometallurgical processes is used, a dehumidification purification device of emission gas must be established.

The specific requirements in the “Access Condition” are separately set towards zinc pyrometallurgical process and the hydrometallurgical process, thus offers protection on mercury reduction.

(3) Prevention of mercury pollution originating from hot acid leaching zinc dross in zinc smelting

"Lead and zinc ore dressing and smelting enterprises should let pollutant treatment technology be feasible, control facilities, operation and maintenance records be complete, the same with the operation of the main production facilities synchronous. The emissions should comply with the relevant requirements of the national "lead and zinc industry pollutant discharge standards"(GB25466-2010[8]) and the total discharge of pollutants can’t exceed the total corporate environmental department approved control targets. The region at which the execution of air pollutants emission limits in particular value, the new lead-zinc project should comply" (GB25466-2010) amendments' requirements. Smelting slag, fly ash and other solid waste must be put into smelting treatment and disposal in accordance with national solid waste and hazardous waste management requirements for disposal or paying the qualified units. When processing zinc-containing secondary materials, fire operations should refer to the national solid waste and hazardous waste management requirements to have sound storage, handling and disposal."

This part regulates conducted emissions of the business, and it must meet the "Lead and zinc industry pollutant discharge standard" (GB25466-2010) requirements[c]. The new lead-zinc project implementation of air pollutant emission limits in particular areas should meet "(GB25466-2010) amendments "requirement. The "lead, zinc industry pollutant discharge standard" (GB25466-2010) and the"(GB25466-2010) amendments" regulate the mercury emissions of the lead and zinc industry enterprises. An overview on legal tools is provided in Table 6.

Table 6: Overview on legislative framework in China between 2005 and 2015

No	Year	File name	Auditing File No
1	2005	Guiding Catalogue of Industrial Structure Adjustment (2005 version)	NDRC No.40 of 2005
2	2006	Specification lead and zinc industry investment behavior, accelerate structural adjustment guidance notice	[2006] 1898 NDRC run
3	2006	The issuance of the "Eleventh Five-Year" comprehensive utilization of resources guidance notice	Development and Reform Commission, Central Information
4	2007	Imported lead placer gold associated ore and concentrates enjoy preferential tax policy matters	General Administration of Customs Announcement No. 14 of 2007
5	2007	Lead and zinc industry access conditions (2007)	NDRC Notice No. 13 of 2007
6	2007	Lead and zinc industry clean production index system (pilot)	NDRC Notice No. 24 of 2007
7	2007	Strengthen the lead and zinc smelting industry, access management notice	NDRC Notice No. 2881, 2007
8	2008	National Mineral Resources Plan (2008-2015)	MLR [2008] No. 309
9	2008	Lead and zinc smelting enterprises energy consumption per unit of product	GB21249-2007
10	2009	Non-ferrous metals industry restructuring and revitalization plan	State council
11	2010	The State Council on ´Notice on Further strengthening the elimination of backward production capacity´	State council notice No. 7, 2010
12	2010	National environmental standards	Lead, zinc and industrial pollutant emission standards
13	2011	Non-ferrous metal industry, "second five" development plan	MIIT
14	2011	Guiding Catalogue of Industrial Structure Adjustment (2011 version)	NDRC No.9 of 2011
15	2011	Lead and zinc industry access conditions (2011 revision)	MIIT
16	2012	Lead and zinc smelting industrial pollution control technology policy	Ministry of Environmental Protection Notice No. 18 of 2012
17	2012	On Efforts to Metal and Nonmetal Mines	State council

[c] Emission standard of pollutants for lead and zinc industry (GB 25466 -- 2010 putting into effect as of Oct. 1, 2010

No	Year	File name	Auditing File No
		Rectification Work	
18	2013	Industrial Restructuring Catalog (2011); 2013 version	NDRC, No. 21, 2013
19	2014	Industrial Restructuring Catalog（2011）	NDRC, No. 21, 2014
20	2015	Standard Conditions in Lead and Zinc Industry (2015)	MIIT, No. 20, 2015

In general, synergistic mercury removal technologies are cost effective and therefore, are easier to promote.

From a macro point of view, China has relatively complete desulfurization and denitration standard systems with many financial incentive policies. The policies on tail gas treatment is also suited for the zinc smelting industries. The financial incentive policies also can be a reference to financial incentive policies for mercury removal in the zinc melting industry.

The current production chain of desulfurization and denitrification equipment is mature, which makes it easier and cheaper to further developing into a synergistic mercury removal technology.

The report concluded that if using synergistic mercury removal technologies, only one device is needed to achieve the multi-purpose of desulfurization, denitrification and removal of mercury. On the other hand, when using dedicated mercury removal technologies, such technology is always in addition to already existing exhaust gas treatment equipment and therefore, two devices are needed to reach the same goal of desulfurization, denitration and demercurization.

Through the pilot enterprises activity, enterprises cannot ensure to meet the discharge standards when equipped only with synergistic mercury removal technology. So, they must continue to improve the efficiency collaborative mercury removal technology, and reduce the cost of dedicated mercury removal technology. A 3-step process as shown in Figure 8.

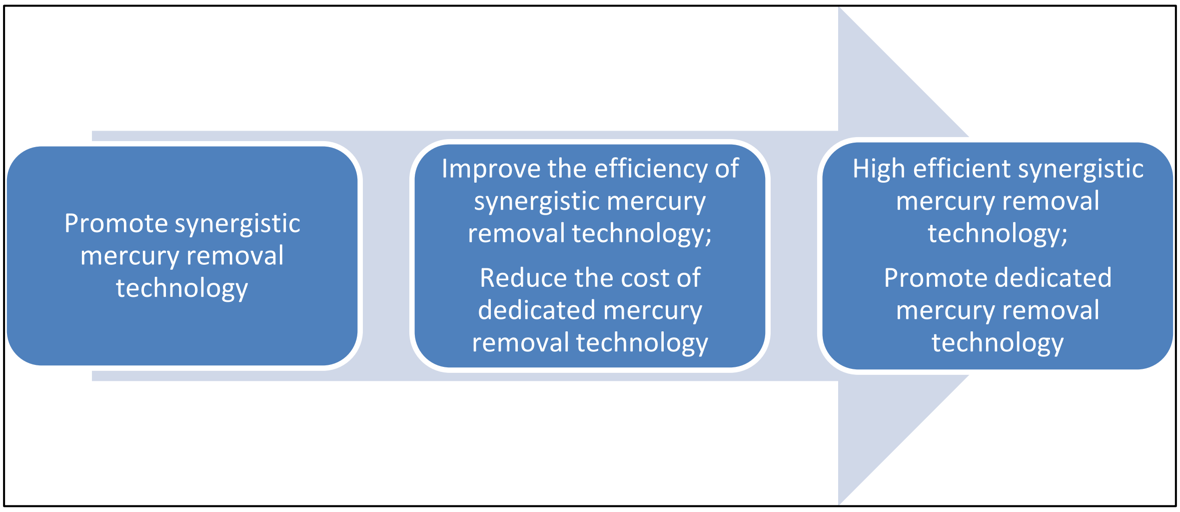

Figure 8: 3-Step approach towards mercury reduction in the zinc smelting industry

For the long-term, China should promote the mercury recycling technology according to local conditions since only through promotion and application of mercury recovery, the mercury pollution can be reduced.

3.2.4 Pilot testing of BAT/BEP measures for emission control in China´s zinc smelters

3.2.4.1 *Shaanxi province –Smelter A*

3.2.4.1.1 General

Shaanxi Zinc Industrial Co., Ltd was formerly known as the ShangLuo smelter. It was the first and largest zinc smelter in Shaanxi province. During the seventh Five-Year Plan (FYP) it was the key project of construction and poverty alleviation in Shaanxi province. The smelter was built in 1987 and it was originally designed to generate an annual output of 8,000 ton of zinc and 12,000 ton of sulfuric acid. The smelter was completed in 1990, received provincial approval in 1993, and started normal operation 1994. In 1994, the Shangluo smelter was transformed to Shaanxi Zinc Industrial Co., Ltd.

From 2006, the company replaced the existing hydrometallurgy system and extended the fluidized bed roasting system to 109 m^2. Further modernization included the leaching residue volatilization processing system, and reconstruction of the leaching, purification, electrolysis and casting system. Currently the company produces 150,000 ton of zinc and 200,000 ton of sulfuric acid every year together with 20,000 tons electric furnace zinc, cadmium ingots (500 tons) and refined indium (10 tons). The raw material that constitutes the input into the smelter is a concentrate whose main ingredient is zinc sulfide, but also contains lead, cadmium, copper, cadmium, mercury, gold, silver, indium, cobalt and other valuable metals. The integrated Shaanxi Zinc Industrial Co., Ltd plant recovers gold, silver, indium, copper, cobalt and other rare metals.

Tsinghua University presented five plans for emission reduction at smelter A[9]:

About 364 kg mercury is discharged from the flue gas of out of sulfuric acid plant in smelter A. This is the main output of gaseous mercury, accounting about 58% of the total discharged gaseous mercury. In order to decrease the releases of mercury from zinc smelter A, five proposals (plans) were made whereby plans 1 through 3 address the gaseous emissions from the sulfuric acid plants, plan 4 targets the emissions from the volatilization kiln and plan 5 the wastewater. Briefly, the five interventions are summarized and valued as follows:

Plan 1: Installation of a desulfurization tower to treat the flue gas from the sulfuric acid plant. Mercury will be present as Hg^{2+}, accounting for 98% of the total mercury. Research has shown that the removal efficiency of Hg^{2+}in the desulfurization tower is between 70% and 95%. Considering the high percentage of Hg^{2+} the flue gas, in addition water washing devices such as a packing tower can be installed at the outlet of the acid plant flue. Such combination would also have the synergistic co-benefit to reduce the SO_2 emission of presently 600 mg/m³ of SO_2in the flue gas below the legal limit value of 400 mg/m³, which is required by Chinese regulation. This change is recommended.

Plan 2: Installation of a Boliden-Norzink mercury removal tower between the sulfuric acid plant and the electric demister. Currently, according to the regulation of the standard of pollution emission of lead and zinc industry (GB 25466-2010), the mercury concentration in the flue gas from the sulfuric acid plant must be below 50 µg m^{-3}. However, this technology requires much higher financial resources and therefore was not recommended for this project.

Nevertheless, plan 2 – installation of a dedicated mercury removal equipment should be considered in the long-term consideration. Besides the Boliden-Norzink technology, which has the widest application worldwide, other technologies exist such as the Outokumpu, Bolkem, selenium scrubber, activated carbon filtration, or selenium filter. Tests had shown that the mercury concentration in the flue gas after the electric demister is about 3276 µg m^{-3}. Compared to the other technologies, the Boliden-Norzink technology seemed to be the most suitable of the before-mentioned to treat such high concentrations of mercury in the flue gas. The removal efficiency could reach 99% theoretically; realistically between 88% and 92% had been achieved (Wang et al., 2010). In summary, the mercury removal facility can reduce the mercury input to the double conversion and double absorption system and recycle it from the flue gas.

Plan 3: Reduce the mercury concentration in the input; *i.e.*, using ores with lower mercury concentration. The ores that are processed in this smelter A contain mercury at concentrations up to 35 ppm. The current air control systems have a removal efficiency of about 96%. In order to meet the legal limit values and such removal efficiency, the mercury concentration in the ores has to be kept below 3.25 ppm. It has to be noted that the mercury concentrations in concentrates using ores from Shaanxi province are much higher than in Hunan province.

About 203 kg Hg or 32% of total gaseous Hg is discharged to the air through the flue gas from the volatilization kiln. It is the second highest source of emission after the flue gas from the sulfuric acid plant. In order to reduce the Hg emission, plan 4 was proposed.

Plan 4: Installation of a special mercury removal facility at the exit of the volatilization kiln. Presently, the mercury concentration at the outlet of the volatilization kiln is about 170 µg m^{-3}; 98% of this is Hg^0. Since water washing devices have little impact on the removal of gaseous metallic mercury and the concentrations are lower than after the sulfuric acid plant, suitable technologies would include the usage of filtration systems such as active carbon or selenium filter or a selenium scrubber.

Plan 5: The sulfuric acid plant discharges about 4,875 kg mercury *per* year, accounting for 56% of the total releases. Usually, the waste water from the sulfuric acid plant is deposited in the water station before release; it contains a large amount of particles (mud). Since mercury can be recycled it is recommended to install a filter to retain the mud and separate from the liquid. Mercury will be concentrated in mud. By depositing the mud, the mercury that flows into the water station will be reduced. Lime/soda can be added to remove the remaining mercury in the aqueous phase to generate a mercury-rich soda/lime, which can be reused by selling to a qualified company for the recycling of mercury. However, according to the national waste management rules, they should be stored airtight in the shadow before reuse.

The mercury content in the sulfuric acid plant of smelter A is 4.93 ppm. This value is lower than the national standard. Smelter A sells about 1.02 ton Hg *per* year of sulfuric acid to the vanadium smelter. In order to decrease the release of mercury, on the one hand, the input should decrease by using low mercury ores or installing a mercury removal tower. On the other hand, mercury in the sulfuric acid could be recycled through purifying technology such as MRT (Molecular Recognition Technology), Toho technology or sulphide precipitation.

The above given plans are based on the mercury flow analysis shown in the figures below. The report from testing that Tsinghua University did undertake a mass balance at the zinc smelter A. It was estimated that 99.68% of mercury into the zinc smelter is contained in the raw material, the zinc concentrate and less than 1% is from coke power and calcine. Inputs into the smelter are shown in yellow-shaded boxed in Figure 9. At the output site (red- and orange-shaded boxed in Figure 9), most of the mercury (55.5%) was stored in the smelter in the form of waste acid; atmospheric emissions accounted for 7.2% and 11.7% of total mercury input was sold out in sulfuric acid.

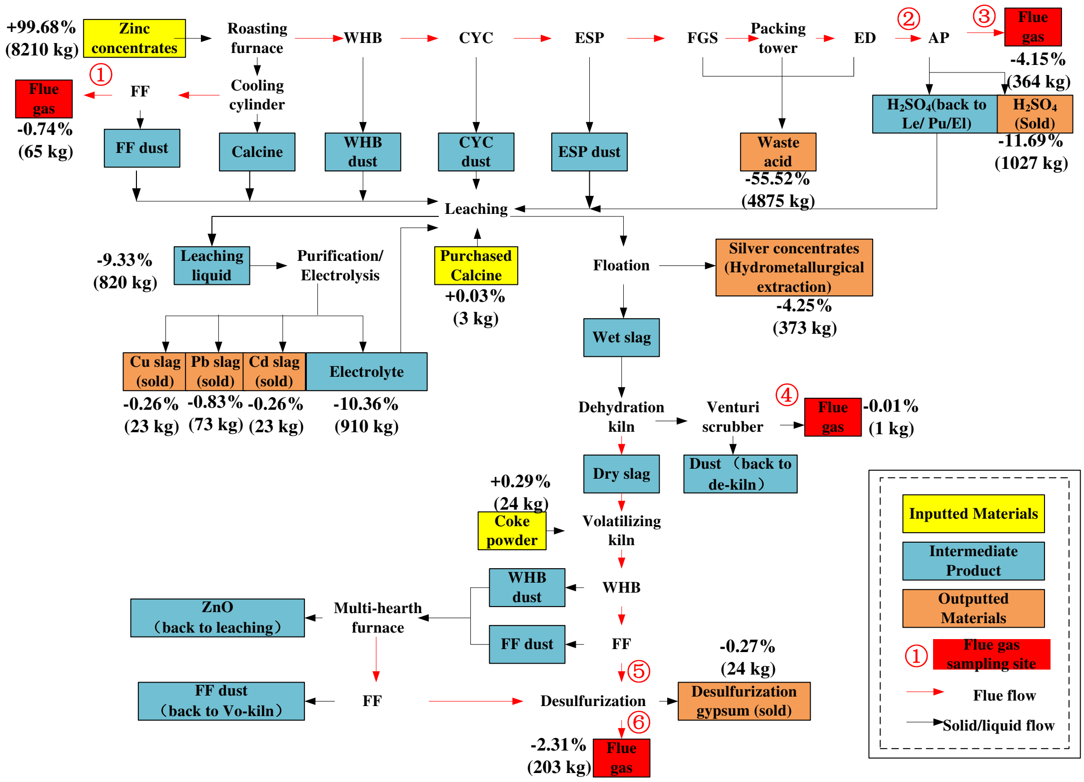

Figure 9: Flow chart for production process in smelter A

To reduce gaseous Hg emission from exhaust roasting gas, smelter A selectively used low-Hg concentrates and installed a desulfurization tower to treat the exhaust gas from the roasting process. This decreased the gaseous Hg emission from 564 µg m^{-3} to 97 µg m^{-3} when concentrates are used that contain about 1 g Hg t^{-1} (0.04 g Hg t^{-1} – 4 g Hg t^{-1}). Since the use of low-Hg concentrates was decided by market, smelter A installed desulfurization tower after double contact and absorption tower to further reduce gaseous Hg concentration. The desulfurization tower mainly reduces oxidized gaseous Hg (Hg^{2+}) and the Hg^{2+} removal efficiency reached 61%. Total Hg removal efficiency of the tower was 56%. With the above two measures, the combined removal efficiency reached 92%.

3.2.4.1.2 Development and testing of BAT/BEP for mercury pollution control

The BAT/BEP measure implemented and tested in Smelter A included three recommended modification in and after the sulfuric acid plant and the volatilization kiln as well as the treatment of the wastewater as shown in the sketch below (Figure 10).

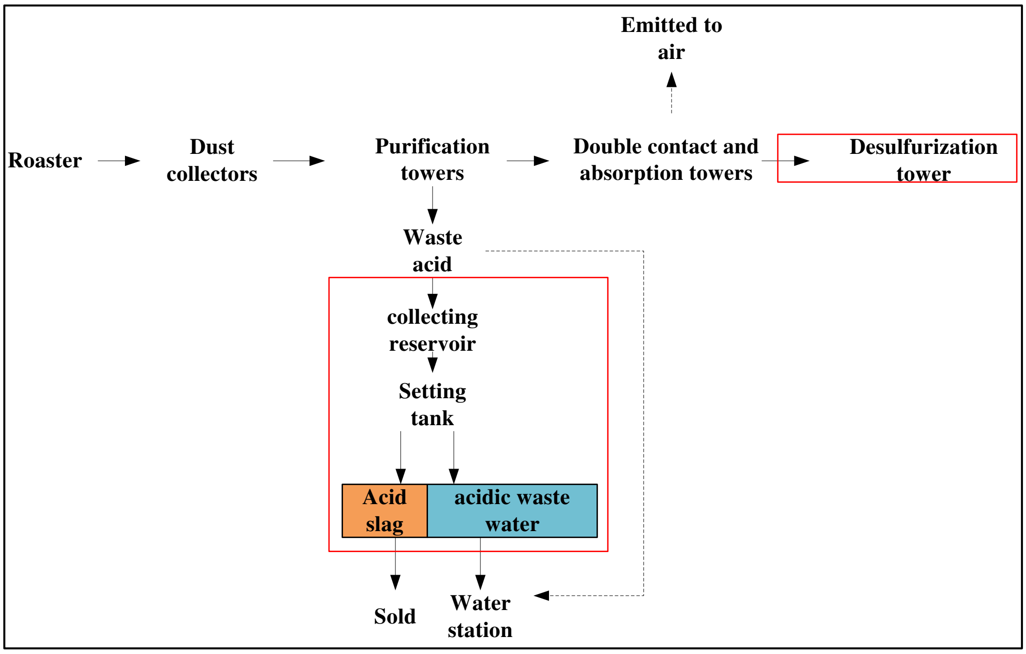

Figure 10: Graphical sketch of the pilot testing steps in smelter A (the dotted line refers to the old process)

(1) Mercury removal in wastewater

The wastewater treatment system was changed and modernized comprehensively including the acid waste water recycling system, settlement system and acid clay filter system. The company used a special flocculent to tackle mercury, installed filters for the recycling of mercury and mud acid in recycling waste water. The investment of this renovation project costed 1.3 million yuan, the acid sludge recycling increased from 50 tons *per* year to 110 tons *per* year.

(2) Mercury recovery in acid production gas

A collaborative mercury technology for desulphurization was introduced to combine zinc oxide desulfurization together with mercury removal technology. This process has the characteristics of low temperature desulfurization process, which is beneficial for mercury removal. The desulfurization efficiency is at 95%, and the absorbent materials (zinc oxide dust) for desulfurization was produced by the company with no purchasing cost. After the desulfurization of zinc sulfate solution for smelting production, there is no by-product, waste residue or wastewater. Exhaust gas SO_2 can achieve stable discharging standard, this technology remove mercury in the flue gas and collection on a regular basis.

3.2.4.1.3 Pollution control

To reduce gaseous Hg emission from the flue gas of the roasting process, smelter A selectively used low-Hg concentrates containing about 1 g t^{-1}Hg (range: 0.04 g t^{-1} to 4 g t^{-1}). Further, a desulfurization tower was installed since low mercury concentrates may not always be available. On May 25-28, 2014, Tsinghua University monitored the mercury in flue gas before and after zinc oxide desulfurization, and the mercury recycle rate of acid wastewater in the field monitoring. The test measurements showed that the gaseous Hg emission decreased from 564 µg m^{-3} to 97 µg m^{-3} (when low mercury concentrates were used). The desulfurization tower showed a removal efficiency reached 61% for Hg^{2+}. The total Hg removal efficiency of the tower was 56%. The two measures combined reached a removal efficiency of 92%.

This utilization of the filtering process for the wastewater and after removing the particulate Hg from the waste acid, the Hg concentration in the waste acid decreased from 84.9 mg L^{-1} to 17.7 mg L^{-1} (meet national standard), the reduction reached 79%. The Hg concentration in the acid slag was about 20% (7%-30%), which is designated for recycling by a qualified enterprise.

The combined mercury release reductions reads as follows:

Mercury reduction in wastewater: (84.9-17.7) mg L^{-1} x 220 m^3/d x 330 d yr^{-1} = **4,879 kg yr^{-1}**

Mercury reduction in acid plant tail gas: 564-19) µg L^{-1} x 65,000 m^3 g^{-1} x24 h x 330 d yr^{-1} = **281 kg yr^{-1}**

Annual mercury release reduction: = 5,160 kg yr^{-1}

The mercury content decreased significantly by preliminary recovery of acid sludge in the wastewater. The company recycled 80 tons *per* year of mud acid with about 20% mercury content in the sludge. This means that the company **recycled 12 tons mercury each year more** than before. By application of the zinc oxide desulfurization, emissions in the order of 281 kg mercury *per* year were reduced.

3.2.4.2 Hunan province - Smelter B

Hunan Shuikoushan Nonferrous Metals Group Co., Ltd. is one of the oldest metal production plants in China: Shuikoushan had China's first lead smelter, China's first zinc oxide plant, China's first smelter for beryllium.

The production process for smelter B is shown in Figure 11. The mass balance showed that 99.6% of mercury input into the smelter is in the form of zinc concentrate. Most of mercury (55.3%) was stored in the smelter in the form of waste acid. Atmospheric mercury was mainly emitted from volatilization kiln.

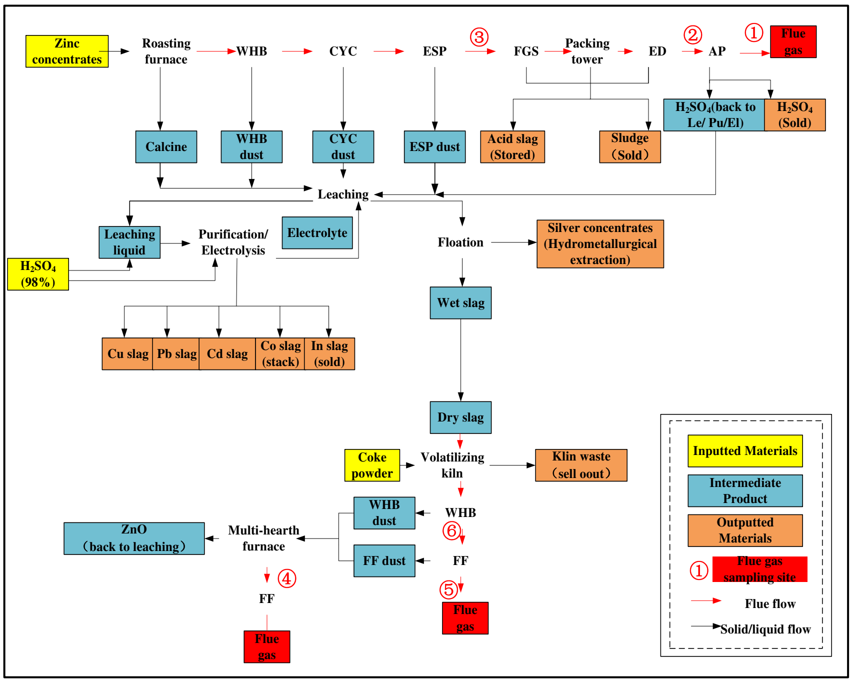

Figure 11: Flow chart for production process in smelter B

The mercury concentration in the roasting gas of smelter B was much lower than that in smelter A. The flue gas from the sulfuric acid plant contained only 4 µg m^{-3}. On the other hand, the mercury concentration in the exhaust gas from the volatilization plant was up to 2826 µg m^{-3}. In contrast to smelter A, the exhaust gas from the volatilization kiln was the most important vector of mercury release to the atmosphere. Based on Hg concentration in the samples, smelter B chose to reduce gaseous Hg emission from exhaust volatilization tower and Hg emission to waste acid. The emission reduction plan for smelter B included

- Installing special mercury removal facilities at the exit of volatilization kiln
- Filter pressing the waste water before the water was put to the water station
- Installing desulfurization tower for the exhaust volatilization flue gas

After installing of the tower, the Hg concentration in the exhaust volatilization gas was reduced to 1,186 µg m^{-3}. The annual Hg emission was reduced to 845 kg *per* year with an annual reduction at 153 kg (report by Shuikoushan Co, 29 April 2015). The Hg^{2+} removal efficiency for the desulfurization tower was 94% while the total Hg removal efficiency was 58%. The flowchart for the process after modernization is shown in Figure 12.

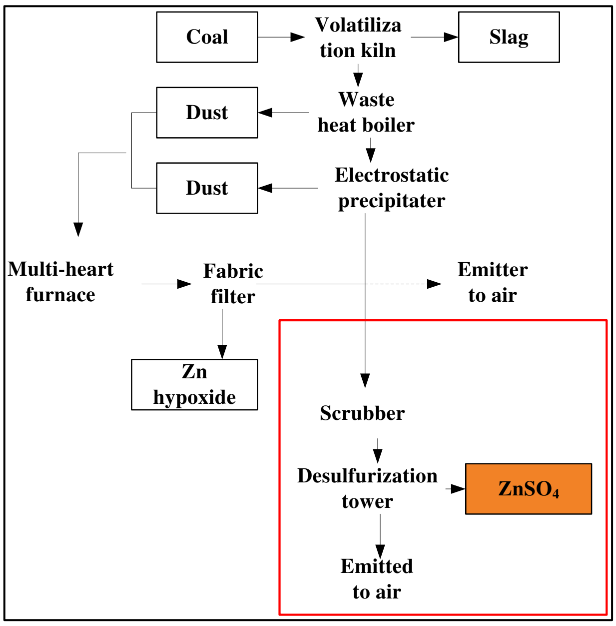

Figure 12: Process flow in smelter B after modernization (installation of desulfurization tower)

The amount of Hg emitted into waste acid annually was 453 kg, accounting for 55.3% of the total Hg outputs of smelter B. After Smelter B had installed filters to recycle particulate Hg in the waste acid, about 138 kg of Hg in the waste acid went into the slag. To further recycle Hg in the acidic waste water, this smelter installed acidic waste water circulation system with the effect that Hg in the acidic waste water was accumulated into gypsum, with an annual reduction of mercury at 15.9 kg through waste water (report by Shuikoushan Co, 29 April 2015). Both, the acid slag and the gypsum were recycled by qualified enterprises.

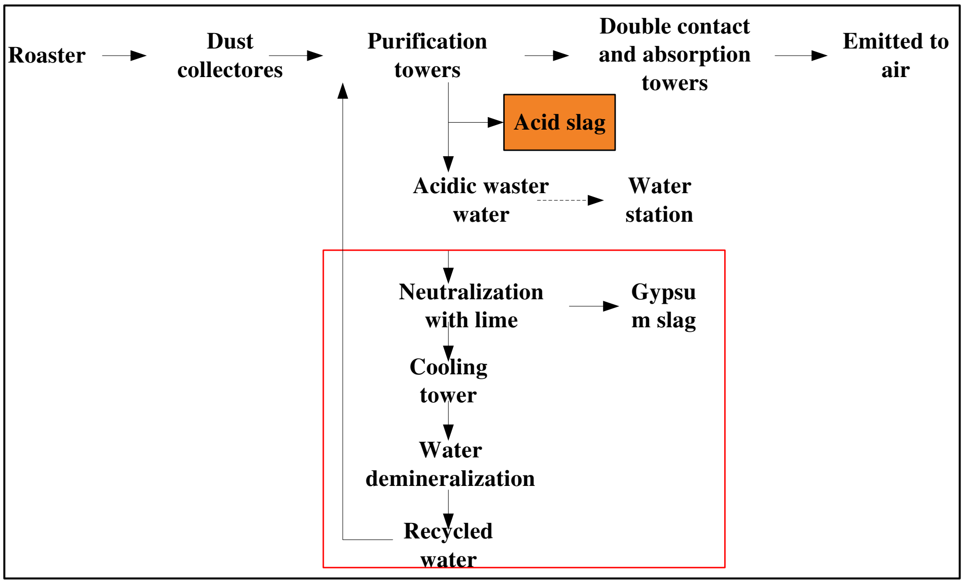

Figure 13: Process flow in smelter B for waste acid after modernization

3.2.5 Definition of technical and policy measures in relation to BAT/BEP in China´s zinc industry

Mercury related provisions on water pollutant emission from zinc and lead industry are shown in the following Table 7. In special protected areas, the limit is 0.01 mg L^{-1}.

Table 7: Mercury-related provisions (mg L^{-1})

enterprise Category	Time quantum	Pollutant	limit value		Emission monitoring location
			Direct emission	Indirect emission	
Existing enterprises	2011.1.1—2011.12.31	Total mercury	0.05		Plant or production facility wastewater outfall
	2012.1.1—	Total mercury	0.05		
New enterprises	2010.10.1—	Total mercury	0.03		Plant or production facility wastewater outfall

Mercury related emissions limit to atmospheric pollution are shown in Table 8

Table 8: Emission limits on atmospheric pollutants in zinc and lead industry (mg/m^3)

enterprise Category	Time quantum	Pollutants	Scope	Emission concentration limits	Emission monitoring location
Existing enterprises	2011.1.1—2011.12.31	Mercury and its compounds	Sintering, smelting	1.0	Workshop or production facilities located in exhaust
	2012.1.1—	Mercury and its compounds	Sintering, smelting	0.05	
New enterprises	2010.10.1—	Mercury and its compounds	Sintering, smelting	0.05	

The emission limit for atmospheric pollutants in existing and new construction enterprises sets a maximum concentration of 0.0003 mg/m³ for mercury and its compounds.

3.2.6 Technical information (as contained in Annex)

3.2.6.1 Sampling and analysis for mercury

Solids such as Zn concentrates, dust (fly ashes) captured by the various APCDs were sampled during measurement periods for *e.g.*, flue gas. About 1 kg of each sample was collected and placed in valve bag until analysis. Liquids such as waste gas cleaning water, sulfuric acid were also taken; a 50 mL of each sample was collected and placed in brown glass bottle at normal temperature until further analysis.

Flue gas sampling from zinc smelter is not an easy task since (1) high concentrations of SO_2 in the flue gas (2-3 orders of magnitude higher than in the gas from power plants) may reduce H_2O_2 and $KMnO_4$ in the absorption unit of the sampling probe resulting in incomplete absorption of mercury; and (2) the mercury concentration in the flue gas from zinc smelters is lower than the detection limit of the U.S. EPA Method 29. This meant that the sampling and analysis procedures and methods had to be adapted to meet the conditions at the zinc smelters. A modified EPA Method 29 had been developed, which allowed the determination of total mercury; it was not suitable for speciation measurements. For Hg speciation, the Ontario Hydro method was applied.

For the analysis of mercury, several processes are known. Among the detectors, the portable Lumex 915M is recommended to analyze atmospheric mercury concentration around zinc smelters considering the variation of atmospheric mercury concentration with both time and space. The cold vapor atomic absorption/fluorescence method is suggested to analyze Hg concentration in solids and liquids.

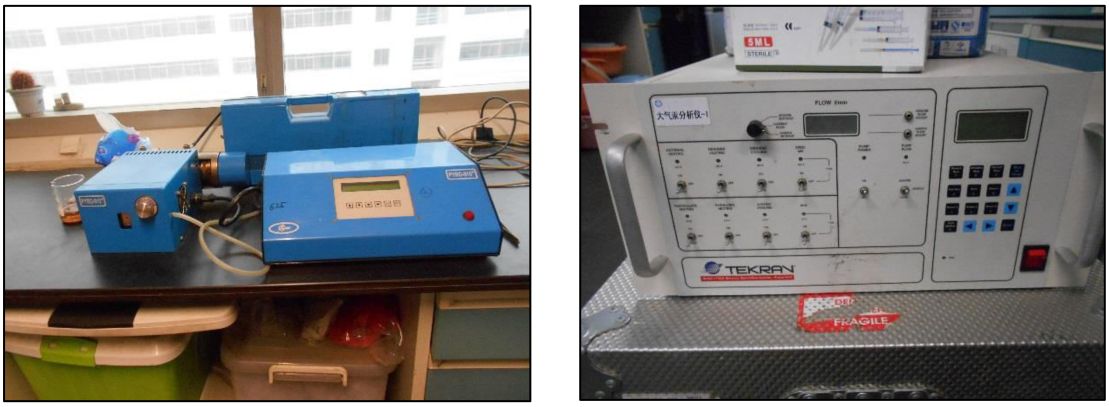

Figure 14: Lumex and Tekran instruments for the analysis of mercury

3.2.6.2 Pollution control measures in the pilot smelters

In the project, the principal subcontractor, Tsinghua University evaluated and assessed the flux of mercury in each of the two plants and made a mass balance. The proposals developed – five plans for the Smelter A and three for the Smelter B – tackled the major release pathways in order to (i) achieve the most significant emission reduction and (ii) to comply with national standards. Subsequently, the BAT/BEP approaches were company-specific and tailored to the processes and local conditions (the latter ones especially the Hg content in the ores).

Each of the company reported to have purchased a desulfurization tower and other equipments at the costs of USD 1,300,000 (MEP/FECO, annual report) as a cofinance contribution to the project. Notably, the desulfurization towers have been installed at different locations within the Zn smelting process.

3.3 Project summary

3.3.1 Fact sheet of the project

The project factsheet is shown in Table 9 (as taken from the CEO endorsement document (4)).

Table 9: Factsheet of the project at project approval (4)

Project Title	Reduction of Mercury Emissions and Promotion of Sound Chemical Management in Zinc Smelting Operations
GEF ID Number	4816
UNIDO ID (SAP Number)	GF/CRP/12/001 (100338)
Country(ies)	China
GEF Focal Area and Operational Program	GEF 5 focal area strategy for chemicals: "to promote the sound management of chemicals throughout their lifecycle in ways that lead to the minimization of significant adverse effects on human health and the environment", in particular Objective 3 to "pilot sound chemicals management and mercury reduction"
GEF Agencies (Implementing Agency)	UNIDO
Project Executing Partner	Ministry of Environment, Foreign Economic Cooperation Office (FECO)
Project Implementation Start Date	16 June 2012
Project Duration (Months)	24
GEF Grant (USD)	$ 990,000
UNIDO Agency Fee (USD)	$ 99,000
UNIDO Inputs (USD)	$ 50,000
Counterpart Inputs - Co-financing (USD) at CEO Endorsement	$ 4,000,000

The financial details at project conclusions are summarized in Table 10and Table 11.

Table 10: Summary of committed/planned and actual finance reports for GEF funds and cofinance (USD)

Project component	Activity type	GEF Financing (in USD)		Co-financing (in USD)	
		Approved	Actual	Promised	Actual
1 Characterization of Hg emissions from Zn smelting	a, b	300,000	326,725	900,000	640,000
2 Demonstration of BAT/BEP	a, b	450,000	464,000	2,490,000	3,280,000
3 Policy reform in Zn smelting industry	a, b	150,000	170,440	250,000	254,000
6. Project management		90,000	28,835	360,000	50,000
Total		**990,000**	**990,000**	**4,000,000**	**4,224,000**

Table 11: Summary of expected and actual cofinance (USD)

Source of co-financing	Type	Project preparation		Project implementation (USD		Total (USD	
		Expected	Actual	Expected	Actual	Expected	Actual
Host gov't contribution	in-kind	N/A	N/A	250,000	195,000	250,000	195,000
Host gov't contrib-ution, activities	in-kind				96,000	-	96,000
GEF Agency (ies)	Grant	N/A	N/A	50,000	50,000	50,000	50,000
Bilateral aid agency (ies)	Grant	N/A	N/A	500,000	500,000	500,000	500,000
Private sector	in-kind	N/A	N/A	2,400,000	2,756,000	2,400,000	2,756,000
Academia	in-kind	N/A	N/A	-	441,000	-	441,000
Local government	in-kind	N/A	N/A	800,000	186,000	800,000	186,000
Total co-financing		-	-	4,000,000	4,224,000	4,000,000	4,224,000

3.3.1.1 Project objectives and structure

The project "Reduction of Mercury Emissions and Promotion of Sound Chemical Management in Zinc Smelting Operations", UNIDO ID: GEF/CRP/12/001, SAP Number: 100338 has the objective to reduce the impacts of mercury from zinc smelting operations on human health and the environment through sound chemical management.

According to the project document, the expected outcomes are:

Outcome 1. Foreign Economic Cooperation Office (FECO) created a coordination and monitoring system for mercury management focusing the zinc smelting sector;

Outcome 2. Best Available Techniques and Best Environmental Practices (BATs/BEPs) adopted for cleaner zinc production;

Outcome 3. FECO developed mercury management policy to facilitate the uptake of BATs/BEPs.

The main project components were:

1. Characterization of Mercury Emissions from the Zinc Smelting Operations in China;
2. Demonstrate BAT/BEP in two pilot plants and evaluate cost effectiveness. Organize public outreach events and share lessons learned with the zinc industry;
3. Develop and promote policy reform to reduce mercury emissions from the zinc smelting industry.

Key project outputs were:

- Mechanisms developed and reforms undertaken by drafting a mercury management policy for supporting the adoption of BAT/BEP in order to reduce mercury release from the zinc industry.
- Identification of alternative production techniques and control mechanisms for the zinc smelting sector through analysis of best available techniques and best environmental practices, and their application in technically feasible pilot projects with two pilot plants that can achieve Hg removal and innocuous treatment from material, smoke pollutants, Hg-containing acidic wastewater and waste solid in zinc smelting process.
- Development of best approach for sound mercury management in other zinc smelting plants in China.
- A database for mercury pollution treatment technologies, cleaner production, end-of-treatment and resource recycling in zinc smelting established. Details can be found in the Project Results Framework in Annex 9 of the ToR.

With the achievements of the above, ultimately, FECO would to be able to successfully monitor mercury emissions and evaluate their impact on human health and the environment from the zinc sector in China. The long-term development and environmental goal of the project, namely to promote the sound management of mercury in China's zinc smelting operations, and to increase the technical capacity for cleaner zinc production in China in order to reduce the emissions of mercury needs to be seen in the future; a goal beyond the timeframe of this project. The identified BATs and BEPs are the technically necessary steps for minimizing adverse effects of mercury on human health and the environment

3.3.1.2 Donors and counterparts

The financier of this project was the Global Environment Facility (GEF) through the POPs window in support of early implementation of the Minamata Convention on Mercury. Substantial cofinance has been provided by the government of China through its Ministry of Environmental Protection (MEP) and the EPBs in Hunan and Shaanxi provinces as well as the two zinc companies in these two provinces.

Throughout the implementation period, the project could benefit from an ongoing bilateral project on mercury ´Sino-Norwegian Cooperative Project on Mercury - Capacity building for reducing mercury pollution (SINOMER II)´ financed by the government of Norway[10].

Besides the Chinese universities, an internal consultant was contracted who provided insight into the following areas:

- best available technologies (BATs) and best environmental practices (BEPs) for mercury emission control in the global Zn smelting sector
- Work plan for the pilot testing of one zinc smelting plant

- Cost-benefit analysis on best available technologies (BATs) and best environmental practices (BEPs) for Chinese authorities

3.3.1.3 *Project timing and duration*

The project implementation was planned to last 24 months starting in June 2012 and to end in September 2014. Upon request from MEP/FECO, UNIDO extended the project to end by August 2015. In order to accommodate the timing of the terminal evaluation, the GEF Secretariat was informed by UNIDO in July 2015 and granted another no-cost extension through December 2015.

3.3.1.4 *Project costs and co-financing*

At approval stage, the project was funded through a GEF grant, amounting to USD 990,000, a UNIDO contribution of USD 50,000, and the counterparts' co-financing of USD 4,000,000. In addition, an Implementing Agency fee amounting to USD 99,000 is to be listed. Detailed information as to the finance of the project and the donors – at endorsement stage – is shown in Table 12 below.

Table 12: Summary of finance at endorsement (Source: (4))

Name of (co-)financier	Type of Financing	Amount (USD)
GEF	**Grant**	**990,000**
Implementing agency fee	**Grant**	**99,000**
Cofinancing:		
National Government FECO	In-kind	250,000
Private Sector Zinc enterprises (Zhuzhou)	In-kind	1,000,000
Local Government Hunan province	In-kind	300,000
Bilateral Aid Agency (ies) Sino-Norwegian projects	Grant	500,000
GEF Agency UNIDO	Grant	50,000
Local Government Shanxi	In-kind	300,000
Local Government Guizhou	In-kind	200,000
Private Sector Shuikoushan	In-kind	700,000
Private Sector Shangluo	In-kind	700,000
Total Co-financing		**4,000,000**

The financial evaluation of this project was performed against the UNIDO contract for the provision of services relating to this project[11]. Following UNIDO´s financial reporting, the final PIR (2015)[12] states the following expenditures according to "sponsored class" (Table 13). Therein, the budget line 2100 refers to the subcontract to the executing agency, MEP/FECO" for the substantive activities during project implementation. The total amount that was transferred to the executing agency was USD 990,000 and included agency/management fee of USD 28,835 corresponding to 3% of the project grant.

Table 13: GEF grant disbursement summary

Sponsored Class*	Amount GEF Grant Disbursed (USD)
1100 - International Experts	7,428.08
1500 - Project Travel	6,077.00
1700 - National Experts	14,981.79
2100 – Subcontract [to executing agency]	961,165.00
3000 - Trainings/Fellowships/Study Tours	
3500 - International Meetings	
4500 - Equipment	
5100 - Sundries	318.21
TOTAL	989,970

*Budget lines are used for the following:
- 1100 – Salaries of professional and above
- 1500 – Travel expenses for project staff
- 1700 – General service salaries, national experts and consultants
- 2100 – Contractual services
- 3000 – Trainings
- 3500 – Conferences and international meetings
- 4500 – Minor equipment
- 5100 – Operating expenses, telephone costs, bank charges

At project closure, the following summary on project achievements, finance spent and cofinance expenditure according to project output has been provided by MEP/FECO as shown in Table 15.

The detailed expenditure report as relates to the budget line 2100 ´subcontracts´ is provided by MEP/FECO as the subcontractor in its role as the executing agency for this project (Table 16). The majority of the GEF grants were in form of subcontracts to the academic institutions in China for the execution of the activities necessary to achieve the requested outputs (47%, USD 456,000). A small part was spent for an international consultant to obtain a global view on zinc production (1%, USD 13,000, BAT/BEP and economic assessment of mercury pollution control at global level. Laboratory costs were USD 49,300, or 5% of the total GEF grant. The EPBs received 6% from the GEF grant amount and the two pilot enterprises only a relatively small share of 25%.

Table 14: Beneficiaries subcontracted from GEF grant to deliver the outputs

Beneficiary	USD	% of total
Universities	456,000	47%
International consultant	13,000	1%
EPBs	60,000	6%
Pilot plants	240,000	25%
Travel, meetings, office fees	99,865	10%
Laboratory costs	49,300	5%
Dissemination	38,000	4%
To be specified	5,000	1%
Total	**961,165**	**100%**

The detailed listing of the co-finance allocations and investments are shown in the tables below including information on co-financing institution/provider, object class and year. A summary of the co-finance on object class is summarized in Table 18. The co-finance committed by the implementing agency UNIDO, is shown in Table 19.

In summary, the financial reports were found complete and consistent. **All activities as postulated in the project document were completed within the budget allocated (GEF grant) of USD 990,000**. The executing agency, MEP/FECO was subcontracted by the implementing agency in one contract made at the onset of the project. The amount allocated for the project activities was USD 961,165. An additional amount of USD 28,835 was transferred as agency fee. These expenditures are also included in the annual report from MEP/FECO and detailed in Table 16 by separate listing.

With respect to the co-finance budget, **the executing agency has to be complemented to having exceeding the requested co-finance by USD 324,000** (Table 17). Comparison of co-finance providers and amounts committed and the final reporting, some deviations have been observed as can be expected for a pilot project and the first of its kind. The following changes occurred and made it possible to reach the project´s objectives:

1. The two pilot plants contributed with more co-finance than originally stipulated (USD 1.3 million in technology development/investment and additionally with infrastructure/office space and human resources).
2. The co-finance by the **Zhuzhou zinc plant** that was listed in the project document at the time of the CEO approval was not used since finally, the Zhuzhou had not been chosen as the pilot plant. Thera son for such decision was that the Zhuzhou plants is equipped with the Boliden-Norzink technology, which, according to the estimation made by the Chinese experts did not have the potential to sufficiently reduce mercury.
3. The co-finance from the local government in **Guizhou province** was not used since after the first screening it was found that there was no plant in Guizhou province that could be used in this project.
4. Activities – a workshop – was organized in **Zhejiang province** although none of the pilot project partners are located in this province. The reason for having a meeting on environmental protection for the non-ferrous metal sector was that the non-ferrous metal industrial association proposed and organized this meeting to disseminate the project study results to more zinc plants. FECO cooperated with the association for this meeting.
5. The **universities** provided substantial co-finance during the implementation of the project as a commitment to the objectives of this project.

Table 15: Project progress matrix in relation to completion, expenditures of GEF funds and cofinance

Out puts		Completion			Expenditures			Cofinance		
	FECO reporting	2013	2014	2015	2013	2014	2015	2013	2014	2015
1.1	Scope of the zinc smelting operations in China evaluated and better understood (data on emissions, exposure, health related)	100%	100%	100%	40,000	-	-	100,000	-	-
1.2	Gap analysis, including comparative analysis against other countries, on institution capacity focusing on zinc industry completed (data on current systems, policies, capacity in China and abroad)	100%	100%	100%	79,000	30,000	-	100,000	20,000	-
1.3	Inception workshop is conducted and inception reports are developed (including the identification of indicators); annual project reports and project implementation reports are developed; annual review meetings are conducted	50%	80%	100%	40,000	4,600	40,000	100,000	20,000	20,000
1.4	FECO is able to successfully monitor mercury emissions and their impact on human health and the environment in the zinc sector	95%	95%	100%	23,125	20,000	50,000	100,000	150,000	30,000
2.1	Two pilot project demonstrations fully implemented	50%	100%	100%	24,000	200,000	-	1,600,000	1,500,000	-
2.2	Lessons learned are disseminated at workshops for future replication (workshops involve private industry, national, regional, and local stakeholders)	30%	80%	100%	-	20,000	100,000	-	50,000	50,000
2.3	Awareness-raised and capacity increased among zinc smelting operators	20%	80%	100%	-	20,000	100,000	-	30,000	50,000
3.1	Assessment of national/local mechanisms, including needs and investment opportunities, to support uptake of BAT/BEP completed	20%	90%	100%	30,000	35,000	15,440	27,200	50,000	15,600
3.2	Guidelines, trainings, and briefs for BAT/BEP developed and promoted in relevant national and local decision-making processes	0%	60%	100%	-	10,000	35,000	-	50,000	20,000
3.3	A national policy plan indicating the required policy reforms is submitted to national authorities for consideration and adoption	0%	50%	100%	-	10,000	35,000	-	61,200	30,000
Project management					12,000	7,500	9,335			
Statistics		47%	83.5%	100%	248,125	357,100	384,775	375,440	2,027,200	1,931,200
Percentage of total					25%	36%	39%	38%	51%	48%
Total reported by FECO		100%			990,000			4,174,000		
Total target		100%			990,000			4,000,000		
Difference (corresponds to administration fee)		**0.0%**			**0**			**- 174,000**		

Table 16: Detailed overview on expenditures from the GEF grant (disbursements by UNIDO, expenditures according to beneficiary and activity)

UNIDO disbursements upon receipt of invoice dated	USD	MEP/FECO progress report period	Expenditure item	USD
Upon signature of the contact by both parties, 12 Oct 2012	150,000	2012/9-2013/3	Inception WS, org	30,000
			Express fee	125
			Subtotal expenditure	30,125
2nd disbursement, 11 Apr 2013	250,000	2013/4-2013/6	Subcontract to Renmin University	21,000
			Subcontract to University of Science and Technology Beijing	40,800
			Subcontract to Tsinghua University	75,000
			Subtotal expenditure	136,800
		2013/7-2013/9	Subcontract to Shaanxi Solid Waste Mang´t Ctr	9,000
			Subcontract to Hunan EPB	9,000
			Subcontract to int´l consultant	5,000
			Subtotal expenditure	23,000
		2013/10-2013/12	Study tour USA, CDN	44,000
			Office fee	2,200
			Subtotal expenditure	46,200
Subtotal 2012/2013	400,000			236,125
Accumulated income	**400,000**		**Accumulated expenditure**	**236,125**
		2014/01-2014/03	Subcontract to pilot plants	72,000
			Subcontract to int´l consultant	3,000
			Lab costs	1,200
			Subtotal expenditure	76,200
		2014/04-2014/06	Subcontract to University of Science and Technology Beijing	68,000
			Lab costs	1,200
			Subtotal expenditure	69,200
3rd disbursement, 21 Jul 2014	250,000	2014/07-2014/09	Subcontract to Tsinghua University	125,000
			Subcontract to int´l consultant	5,000
			Meeting	800
			Lab costs	1,200
			Subtotal expenditure	132,000
		2014/10-2014/12	Subcontract to Hunan pilot plant	36,000
			Subcontract to Renmin University	35,000
			Lab costs	1,200
			Subtotal expenditure	72,200
Subtotal 2014	250,000			349,600
Accumulated income	**650,000**		**Accumulated expenditure**	**585,725**
4th disbursement, 2 Mar 2015	210,000	2015/01-2015/12	Subcontract to Hunan EPB	21,000
			Subcontract to Shaanxi EPB	21,000
			Subcontract to Hunan pilot plant	84,000
			Subcontract to Shaanxi pilot plant	48,000
			Subcontract to Renmin University	14,000
			Subcontract to University of Science and Technology Beijing	27,200
			Subcontract to Tsinghua University	50,000
			Subcontract for international consultant, Terminal evaluation	30,000
			Subcontract for national consultant, Terminal evaluation	10,000
			Expert fees for meetings	3,000
			Translation for project report	1,500
			Business trip	1,180
			Dissemination materials	38,000
			Meeting	21,560
			Audit	5,000

UNIDO disbursements upon receipt of invoice dated	USD	MEP/FECO progress report period	Expenditure item	USD
5th final payment, 28 May 2015	101,165			
Subtotal 2015	311,165			375,440
Accumulated income	**961,165**		**Accumulated expenditure**	**961,165**
1st+2nd disbursement, 11 Apr 2013	12,000		Management fee 2012/2013	12,000
3rd disbursem´t, 21 Jul 2014	7,500		Management fee 2014	7,500
4th disbursem´t, 2 Mar 2015	6,300		Management fee 2015	9,335
Final, 28 May 2015	3,035			
Agency fee total	**28,835**		**Agency fee total**	**28,835**
GRAND TOTAL	**990,000**			**990,000**

Table 17: Co-finance budget according to provider of co-finance and object class

MEP/FECO Annual report	Co-finance - Expenditure item	No.	Repetitions (often months)	Unit cost (USD)	Subtotal (USD)	% spent of total
2013	Office FECO	1	12	5,000	60,000	
	Office Tsinghua University	1	12	4,000	48,000	
	Office USTB	1	12	4,000	48,000	
	Office Renmin University	1	12	4,000	48,000	
	Office Hunan EPB	1	12	2,500	30,000	
	Office Shaanxi EPB	1	12	2,500	30,000	
	Office Smelter B	1	12	2,000	24,000	
	Office Smelter A	1	12	2,000	24,000	
	Subtotal expenditure				**312,000**	
	Personnel FECO	3	12	500	18,000	
	Personnel Tsinghua University	3	12	300	10,800	
	Personnel USTB	3	12	300	10,800	
	Personnel Renmin University	3	12	300	10,800	
	Personnel Hunan EPB	3	12	200	7,200	
	Personnel Shaanxi EPB	3	12	200	7,200	
	Personnel Smelter B	3	12	200	7,200	
	Personnel Smelter A	3	12	200	7,200	
	Subtotal expenditure				**79,200**	
	Desulfurization tower Smelter B	1	1	800,000	800,000	
	Desulfurization tower Smelter A	1	1	800,000	800,000	
	Subtotal expenditure				**1,600,000**	
	Activities					
	Research survey, Hunan	25	2	60	3,000	
	Research survey, Hunan and Shaanxi	50	4	80	8,000	
	Pilot plant WS	50	2	50	5,000	
	Two WS in Hunan and Shaanxi	50	8	50	20,000	
	Subtotal expenditure	**175**			**36,000**	
	Subtotal Year				**2,027,200**	**51%**
2014	Office FECO	1	12	5,000	60,000	
	Office Tsinghua University	1	12	4,000	48,000	
	Office USTB	1	12	4,000	48,000	
	Office Renmin University	1	12	4,000	48,000	
	Office Hunan EPB	1	12	2,500	30,000	
	Office Shaanxi EPB	1	12	2,500	30,000	
	Office Smelter B	1	12	2,000	24,000	
	Office Smelter A	1	12	2,000	24,000	
	Subtotal expenditure				**312,000**	

MEP/FECO Annual report	Co-finance - Expenditure item	No.	Repetitions (often months)	Unit cost (USD)	Subtotal (USD)	% spent of total
	Personnel FECO	3	12	500	18,000	
	Personnel Tsinghua University	3	12	300	10,800	
	Personnel USTB	3	12	300	10,800	
	Personnel Renmin University	3	12	300	10,800	
	Personnel Hunan EPB	3	12	200	7,200	
	Personnel Shaanxi EPB	3	12	200	7,200	
	Personnel Smelter B	3	12	200	7,200	
	Personnel Smelter A	3	12	200	7,200	
	Subtotal expenditure				**79,200**	
	Sino-Norwegian project	1			500,000	
	Subtotal expenditure				**500,000**	
	Desulfurization equipment Smelter B	1	1	500,000	500,000	
	Desulfurization equipment Smelter A	1	1	500,000	500,000	
	Subtotal expenditure				**1,000,000**	
	Activities					
	Three WS in Hunan province	120	6	42	30,000	
	One WS in Zhejiang province	100	2	50	10,000	
	Subtotal expenditure				**40,000**	
	Subtotal Year				**1,931,200**	
	Accumulated expenditure				**3,958,400**	**99%**
2015	Office FECO	1	6	5,000	30,000	
	Office Tsinghua University	1	6	4,000	24,000	
	Office USTB	1	6	4,000	24,000	
	Office Renmin University	1	6	4,000	24,000	
	Office Hunan EPB	1	6	2,500	15,000	
	Office Shaanxi EPB	1	6	2,500	15,000	
	Office Smelter B	1	6	2,000	12,000	
	Office Smelter A	1	6	2,000	12,000	
	Subtotal expenditure				**156,000**	
	Personnel FECO	3	6	500	9,000	
	Personnel Tsinghua University	3	6	300	5,400	
	Personnel USTB	3	6	300	5,400	
	Personnel Renmin University	3	6	300	5,400	
	Personnel Hunan EPB	3	6	200	3,600	
	Personnel Shaanxi EPB	3	6	200	3,600	
	Personnel Smelter B	3	6	200	3,600	
	Personnel Smelter A	3	6	200	3,600	
	Subtotal expenditure				**39,600**	
	Activity: Field visit to two pilot plants	1	1	20,000	20,000	
	Subtotal expenditure				**20,000**	
	Subtotal Year				**215,600**	
	Accumulated expenditure				**4,174,000**	**104%**
	Target = co-finance committed without UNIDO				4,000,000	
	Balance (Additionally)				**174,000**	

Table 18: Summary of co-finance spending according to object class

Itemization	USD
Office costs	780,000
Personnel	198,000
Technical transformation	2,600,000
Sino Norwegian project	500,000
Activities	96,000
Grand total	**4,174,000**

Table 19: Co-finance budget by implementing agency (UNIDO)

Year	Expenditure (Dollars)	Purpose
2012	4,898	UNIDO staff travel
2013	none	Not applicable
2014	12,000	UNIDO staff travel and international consultant fees
2015	3,630	International consultant travel
Total	20,528	

3.3.2 Brief description including history and previous cooperation

UNIDO is one of the GEF implementing agencies with numerous projects under Focal Area Chemicals and Wastes (under GEF5 as POPs). Currently, UNIDO is implementing 36 GEF full- and medium-size projects related to chemicals management, worth nearly USD 130 million and 70 enabling activity projects worth up to USD 18.5 million. China is a long lasting and well known partner for UNIDO in the implementation of GEF projects, and has currently six active projects worth USD 31 million.

Specifically, UNIDO has already established a solid working relationship with FECO through cooperation in the area of POPs management. In addition, given the nature of the project, which is focused on pilot testing, capacity building, awareness raising, health risks to local communities' reduction and policy development, climate change will have limited impact on achievement of the project's objectives. However, the following possible risks still exist and could prevent the achievement of project objectives

3.3.3 Project implementation arrangements and implementation modalities

The project structure is laid down in the CEO endorsement document. The sketch below (Figure 15) shows the implementation arrangements followed by a narrative.

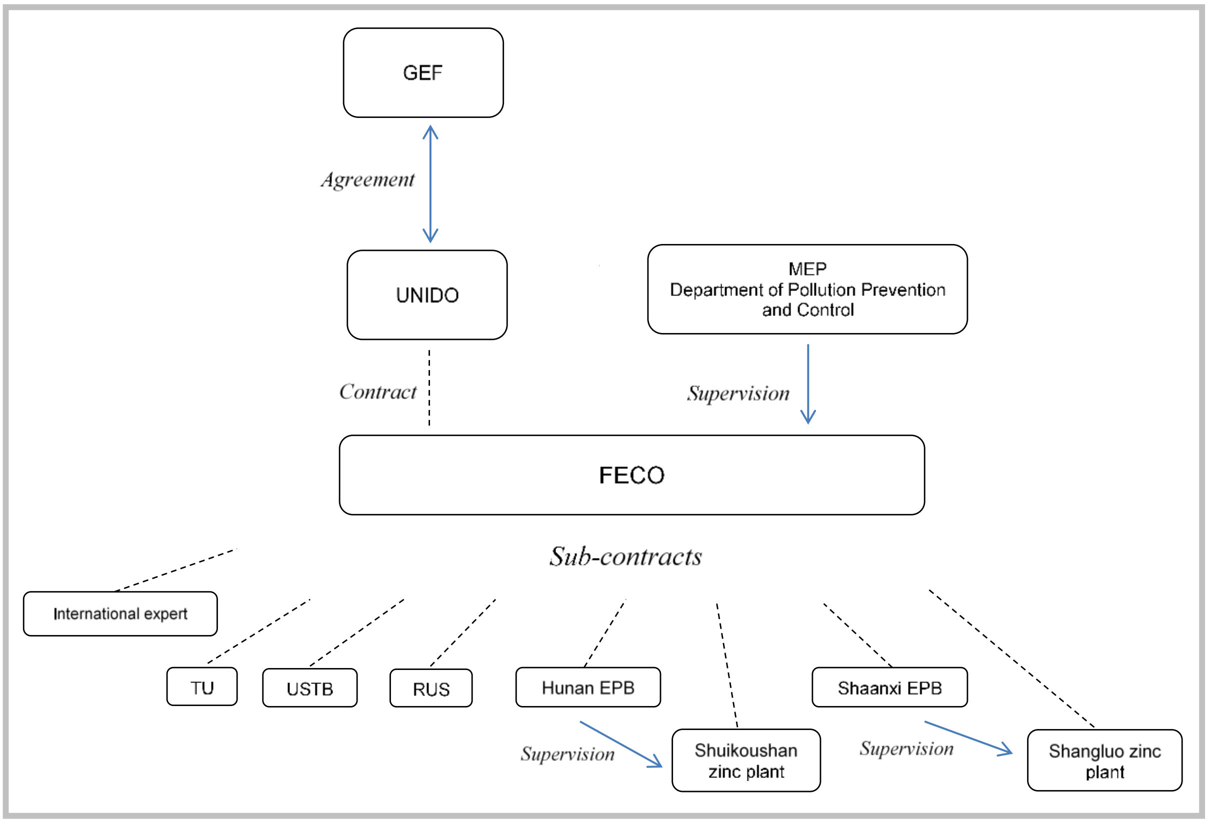

Figure 15: Sketch of project organization structure

UNIDO is responsible for overall project monitoring and evaluation, and reporting progress to the donor (Source 4). UNIDO conducts yearly monitoring and evaluation visits to China, and submits programmatic and financial interim reports within 30 days of the end of every six-month period. The final programmatic and financial reports will be submitted to the donor within 90 days of project end. UNIDO and FECO, as the main executing partner, will meet biannually to

1) review and approve annual work plans;
2) assess progress against M&E targets as indicated in the Project Results Framework;
3) approve of interim and final reports; and
4) assess any gaps or weaknesses, and make and appropriate adaptive management decisions based on progress and achievements.

Work plans for years two will be based upon results achieved in the previous year, agreed priorities and any changes identified via adaptive management decisions (including associated budget allocations).

Programmatic M&E: FECO as the executing agency is responsible for day-to-day management of the project and monthly reporting from the field, and quarterly reporting to UNIDO. The small Project Management Unit (PMU) consisted of a Project Manager (PM) and a Project Assistant (PA), both at the Division at FECO.

The PM will report regularly on project management matters to the Project Executive which will in turn report to a Project Executive Board (PEB). This is the highest policy-level body of the parties in FECO directly involved in the implementation projects.

3.3.3.1 Institutions involved

Global Environment Facility: The Global Environment Facility (GEF) addresses global environmental issues while supporting national sustainable development initiatives. It does so through a partnership involving 176 member countries, ten agencies, recipient countries, non-governmental organizations, and the private sector. The Global Environment Facility Trust Fund is one of the two financial mechanisms for the Minamata Convention to provide new, predictable, adequate and timely financial resources to meet costs in support of implementation of this Convention as agreed by the Conference of the Parties.

Implementing agency:	UNIDO (United Nations Industrial Development Organization)
Executing agency:	MEP/FECO (Ministry of Environment (China), Foreign Economic Cooperation Office as the executing agency)
Government sector:	Environmental Protection Bureau, Hunan province Environmental Protection Bureau, Shaanxi province
Academia:	Renmin University of China, Beijing Tsinghua University (Beijing) University of Science and Technology Beijing
Private sector:	Shaanxi Zinc Smelting Co., Shangluo Hunan Shuikoushan Non-ferrous Metals Group Co., Ltd.
International consultant:	Jozef Pacyna

3.3.3.2 Major changes to project implementation

No major changes were made or necessary.

3.3.4 Positioning of the UNIDO project

UNIDO's mandate is to promote the eradication of poverty through the promotion of sustainable productive activities. The organization is committed to introducing technological solutions in an integrated manner to issues that adversely affect human health and the environment. UNIDO has experience in mercury reduction projects in different regions of the world. UNIDO has a field office in China, which can assist in facilitation and interaction with the Chinese counterparts on both the national and local level. Through this experience, a strong rapport has been established with international, national, and local stakeholders. This will in turn facilitate the implementation of the proposed project (Source (4)).

Since its inception, UNIDO has been an active partner of the Global Mercury Partnership, taking the lead in the artisanal and small-scale gold mining area and joining as an active partner in the mercury in product, mercury in waste and chlor-alkali areas. In these various areas, UNIDO's role is to provide technical guidance based on its experience of the industrial sectors. UNIDO is currently implementing and developing a number of projects in the area of mercury pollution control including addressing the issue of mercury use in artisanal and small-scale gold mining together with GEF and other partners, managing mercury content in compact fluorescent lamps with the Quick Start Programme (QSP) of the Strategic Approach for Chemicals Management (SAICM) (Source (4)).

3.3.4.1 Other donors

The government of Norway committed co-finance through its bilateral project SINOMER II "Sino-Norwegian Cooperative Project on Mercury - Capacity building for reducing mercury pollution" at an amount of up to USD 500,000. The co-finance helped the Chinese executing agency and its partners at initial stage of the project with respect to international and sectoral expertise.

3.3.4.2 Private sector

The private sector provided substantial co-financing through the two zinc companies that did undertake the pilot testing and the zinc sector. The details can be seen in Table 12 at the onset of the project and in Table 15 at project closure. Whereas the total co-finance from the three private sources amounted to USD 2,756,000 at the time of the project submission and approval (year 2012), the final co-finance contribution was exceeded and amounted to USD 4,174,000.

4 PROJECT ASSESSMENT

4.1 Design

The project has been developed and approved for funding before the text of the Minamata Convention on Mercury was concluded. Without the guidance from the Convention text, the evaluation found that the project was well designed and adequate to address the problems at hand or the needs of the Minamata Convention.

More specifically, the project design provided a good basis for addressing the problems associated with zinc smelting, particularly by focusing on the areas of most concern. This pilot project provided practical feedback on the effectiveness of technology both from a technical view point and also with a view on economic consideration. As mercury emissions from zinc smelting are identified as a source controlled under the Minamata Convention (as part of the cluster of ‘smelting and roasting processes used in the production of non-ferrous metals´), the project provides very useful baseline information and a start to activities which will be required during the implementation of the Minamata Convention.

The project clearly identified the following:

- Clear and focused on one important industrial sector;
- Stakeholders clearly identified;
- Geographic location (national);

No changes to project structure occurred. However, the evaluation team also noted that output 1.4 ´FECO is able to successfully monitor mercury emissions and their impact on human health and the environment in the zinc sector´ is a too ambitious statement and out of scope of this project. The evaluator is not aware of any defined/proven direct effects on negative impact on the general population that can be attributed to exposure to mercury from non-ferrous metal industry or atmospheric emissions. Further, the impact on human health from chronic exposure to mercury emissions cannot be derived from a one-point in time project.

4.2 Relevance

With respect to the extent, the project is relevant to the national development and environmental priorities and strategies of the government and the population of China, and especially with respect to regional and international agreements. The project supported a priority in the recipient country – China – and assisted the country to tackle the challenges towards a new international agreement but also enabled the country to take an active part during the negotiation of the Minamata Convention.

GEF-funded projects should be country-driven and in agreement with the focal areas/operational programme strategies of the GEF. This project was CEO approved in 2012 and was the first project by the GEF to fund mercury-related activities. This project was part of the wider portfolio of the GEF 5 Focal area strategy for chemicals “to promote the sound management of chemicals throughout their lifecycle in ways that lead to the minimization of significant adverse effects on human health and the environment”, in particular to Objective 3 to “pilot sound chemicals management and mercury reduction”. More concretely, the project should make special contribution to the new International Mercury Treaty (Minamata Convention on Mercury).

In a narrow sense as stated in the summary of the GEF 5 strategy on chemicals[13] ´The GEF-5 strategy for chemicals sets to consolidate the persistent organic pollutants and ozone layer depletion focal areas, as well as to broaden the scope of GEF's engagement with the sound management of chemicals and **to initiate work on mercury**´, this project "initiated work on mercury". Subsequently, the GEF allocated USD "20 million allocation to directly support sound chemicals management activities that generate global environmental benefits (in other words: SAICM), and will support the development of the mercury treaty with pilot activities in a manner similar to the successful activities that the GEF supported during the negotiations for the Stockholm Convention" [13]. The allocation for mercury projects was USD 10 million.

While the project did not have direct impact of the development of text in the Minamata Convention, it provided a concrete example of mercury control from the smelting of zinc ores. The Convention identifies four non-ferrous metals with a potential to emit large amount of mercury when smelted. Therefore, the project contributed to identifying solutions for future provisions and guidance to support the Convention's implementation.

The attempt was successful that the project document highlights the relevance of the national priorities in wider pollution control and reduction of pollutants into the environment. The project is particularly relevant for the Minamata Convention on Mercury, as the results from the pilot studies will contribute to the information available on the control of emissions from zinc smelters. It is anticipated that the national communication of the outcomes will assist other plants in moving towards emission reduction, and will facilitate the introduction of best available techniques and best environmental practices, in particular at new installations. The interim secretariat of the Minamata Convention would be interested in exploring options for cooperation to disseminate this experience to other countries involved in zinc smelting, to assist them in the decision making process in relation to emission reduction.

4.3 Effectiveness

This mercury project in the zinc industry has some remarkable achievements including:

- Project approval, especially since this was the first mercury project approved by the GEF;
- Highly relevant and timely at the beginning of the mercury convention negotiations;
- Institutional capacities built; complemented by UNEP/GEF project on initial mercury inventory, NIP, MIA;
- Input into the ongoing BAT/BEP guideline discussions (Minamata process);
- Contribution from developing country;
- Before the project, there was no monitoring and evaluation system;
- Capacities for the monitoring of mercury (in zinc plants) have been identified and strengthened (TU, USTB, local EPBs, enterprises);
- Conclusive and realistic initial economic assessments provided (pollution control; refinance)

4.3.1 At national level

Neither the implementing nor the executing agency established dedicated Webpages for this project. Therefore, it might be difficult to follow progress in implementation and effectiveness after project closure.

However, the executing agency, MEP/FECO, provided information *via* the following Webpages:

http://en.mercury.org.cn/cooperation/201402/t20140224_21783.html

http://en.mercury.org.cn/news/201404/t20140402_21929.html

http://en.mercury.org.cn/news/201312/t20131225_21383.html

The project has generated results that could lead to changes of the assisted institutions as follows:

The project provided Government counterparts in China with the tools to control mercury emissions from zinc smelters by building upon best practices worldwide and a detailed inventory of the current zinc production in the country. The demonstration sites are a clear indication of the applicability of the solutions in the Chinese context.

4.3.2 At international level

With respect to outputs or outcomes generated that have fed into the negotiations of the Minamata Convention or the development of guidance to facilitate the implementation of the Convention or any other actual and/or potential longer-term impacts, more than indicative steps or catalytic effects have been achieved.

It is challenging to identify direct contributions from this project into the guidance developed to facilitate the implementation of the Convention. A group of technical experts has worked since February 2014 on guidance on mercury emissions, with a Chinese expert from Tsinghua University leading work on emissions resulting from coal combustion in coal-fired power plants and coal-fired industrial boilers. However, the guidance on reduction of mercury emissions from non-ferrous metals does not include specific references drawn from this project, potentially as the work is not yet completed. One outcome from the Sino-Norwegian project is referenced in the guidance document, however it is not clear whether this was directly part of the project, or whether it was an independent activity. It is anticipated that the work of this project will contribute to case studies for this sector, and may be useful during revisions of the guidance, as more information is made publically available.

The development of training and briefing on how to implement measures to reduce air emissions will be useful both in China and in other countries as they select suitable measures for control of the this sector. Information on the cost-effectiveness of measures is likely to be particularly useful in assisting plant managers and regulators to select appropriate techniques.

4.4 Efficiency

The project was cost-effective considering the scale of the sector in the country and the inclusion of pilot large-scale testing at two production plants. On the other hand and from a managerial aspect, the project could have benefitted from a closer cooperation with a UNEP-led initiative in the country.

The interim secretariat had no comments in relation to how cost-effective the project has been. At the time of implementation of the project, there was little other coordinated work underway to address mercury emissions from the sector, so the opportunity for cooperation was limited. The increasing awareness of the emissions from the zinc sector, and particularly the awareness of techniques which may be effective to reduce these emissions, may have contributed to the inclusion of zinc production in the overall category of non-ferrous metals during the negotiation of the treaty.

In more detail, the evaluation team found that as a MSP project (< 1 mio USD), the project was very efficient by

- Pilot testing at two zinc production plants as planned in the project document;
- Identifying the critical steps and emissions in the production process;
- Creating a network of information exchange and capacity building in both industry and academia;
- Optimizing the sampling trains for mercury stack measurements;
- Mass balance of mercury in zinc smelters established;
- Methods for monitoring Hg emission from zinc smelting industry were formed as a potential national standard;
- The best available technology (BAT) and best environmental practices (BEP) for mercury emission control have been tested and successfully applied techniques forwarded for further policy and technology recommendations;
- Mercury emission control technology and policy were produced for China's zinc smelting industry;
- Policy recommendations for national and international control of mercury pollution in zinc industry.

4.5 Sustainability of Project Outcomes

Sustainability is understood as the likelihood of continued benefits after the GEF project ends. This assessment should explain if there are any exogenous or endogenous risks to the project outcomes that will affect continuation of benefits after the GEF project ends. Risks include: financial risks, sociopolitical risks (*e.g.,* insufficient stakeholder ownership), institutional framework and governance risks, and environmental risks.

In the project document at CEO endorsement), four risks were identified which were either medium (3) or low (1) (Table 20).

Table 20: Risks and mitigation measures identified at stage of CEO endorsement

Risk	Risk level	Mitigation Measure
Estimation of national mercury emissions from zinc smelting sector is not readily available and cannot be measured	Low	Given the extent of the 1999 data, collection of China's national mercury emissions from the zinc sector should not encounter significant problems
National, regional, local governments, and zinc smelting communities do not stay engaged, provide support, nor remain interested in promoting sounds management of mercury	Medium	The project will rely on MEP, local municipalities, national and local experts to engage the remaining relevant stakeholders of the project. Given previous experience with POPs projects, we do not foresee major problems
National, regional, local stakeholders are not receptive to awareness training and unwilling to adopt new technologies that reduce mercury emissions and	Medium	Through the INC process, China is expected to serve as a leader for the participating countries facing similar issues. The project team will continue to publicize the project at the national and global level, therefore unwillingness to

Risk	Risk level	Mitigation Measure
health risks, and are economically viable		adopt changes and new technologies is unlikely to occur
No alternative or appropriate mercury control technologies for the zinc production process in China	Medium	Though the status of zinc production process in China is very complex, the appropriate technologies may be developed through pilot demonstration, furthermore, the new technologies also could be introduced from developed countries by this project

For all of the four risks, the mitigation measures listed have been successful and the project activities related to these risks have been successfully completed so that the risks do not exist any longer.

The sustainability of the project at the demonstration sites is considered quite secure by the implementing agency (UNIDO) and the evaluation team. However, the replication and multiplication relies mostly on the will of the Government counterparts to disseminate the results and the enforcement of the control measures by regulatory authorities.

As the work of this project relates directly to the obligations of the Minamata Convention on Mercury the benefits are likely to continue, particularly given the commitment China has expressed to the implementation of the Convention.

4.6 Assessment of monitoring and evaluation systems

AM&E plan was implemented according to GEF and UNIDO guidelines including:

- Project reports (MEP/FECO to UNIDO) – annually and quarterly;
- Project implementation reviews (UNIDO to GEF) - annually
- Financial reports – regularly at quarterly basis
- Technical reports – according to workplan

The implementing agency stated that the project did not include a monitoring component and this is where the collaboration with the UNEP-led initiative could have been beneficiary. As in both cases the project was executed by FECO, it is hoped that the integration of both projects’ results will happen at the national level.

4.7 Monitoring of long-term changes

The establishment of the baseline for mercury emissions from the zinc smelting industry is a first important step, which needs to be followed up.

New networks between government and enterprises and with academia have been created since in all three groups, project teams were set-up. The continuation of these cooperations beyond awareness raising and capacity building needs to be secured. Some of the future activities will need to be continued when China becomes a party to the Minamata Convention.

Through the development of new standards and legislation – some not yet concluded – a certain degree of future commitment or obligation is inherent in the process. At this stage, future compliance mechanisms cannot be judged and enforcement measures need to be developed.

The interim Secretariat found that the project document indicated the development of a monitoring system. Should China become a Party to the Minamata Convention, they have an obligation to develop an inventory of emissions from zinc smelters, and to provide updates on these emissions in order to demonstrate that the measures they are taking are providing reasonable progress in reducing emissions over time. The monitoring system developed under this project will assist in providing this information. It shall be noted that the Minamata Convention on Mercury is still not yet in force (July 2016).

4.8 Assessment of processes affecting achievement of project results

4.8.1 Project planning and implementation

The questions to assess were: From your point of view/involvement into the project, was the project concept in line with the sectoral and development priorities and plans of the country? Were the relevant country representatives from government and civil society involved in the project visible to the international community?

From the implementing agency´s view, the wide representation of stakeholders in the project was successful.

Monitoring and self-evaluation were carried out effectively, based on indicators for outputs, outcomes and impacts. Regular contacts between the implementing agency and the executing agency ensured good monitoring and this was complemented by an annual monitoring mission from the Implementing agency.

Outside partners such as the interim secretariat was not closely involved with the project, and is not able to provide input to this question.

The evaluation team found that **quality at entry and throughout** the project were high since highly qualified partners at academic level (leading universities), buy-in from provinces (EPB), and two pilot enterprises actively participated in the project.

No changes from approved document during implementation was observed. Since this was a single country project, the commitment to national implementation and country priority was high. The project was implemented within budget and with extension at no costs to the GEF. Substantial cofinance contributed significantly to outputs and demonstrated the commitment of partners and high importance of the project at national level.

With respect to communication and outreach and due to the highly technical nature of the project, emphasis was successfully put into the establishment of new networks within and between enterprises, academia and government (national and provincial level). Several project workshops were held and a Website of MEP/FECO informed about main activities. Further, some featured new articles were authored and several occurrences in television were done.

Slight delays occurred due to harmonization needs in activities such as adjustments for scheduling of sampling activities at the pilot plants.

4.8.2 Financial planning (GEF funds and co-finance)

The source of information is the reporting by MEP/FECO in quarterly progress reports[14] (four reports in 2013, four in 2014, and a narrative/financial report in 2015 during the terminal evaluation) and annual reports[15] (three reports in total for the years 2013, 2014, and 2014). The expenditure reporting has been matched with the UNIDO progress reporting and the PIR reporting[16] (see section 3.3.1.4). From the GEF funds, as expected, most was spent to achieve output 2.1 ´Two pilot project demonstrations fully implemented´ (USD 224,000; corresponding to 23% of the GEF funds). Of this, the main expenditure occurred in 2014 (USD 200,000), the second year of project implementation. In general, individual instalments were quite low and only for output 2.1, a larger "at once" expenditure occurred.

Similar to the disbursement of the GEF funds, the vast majority of the co-finance, namely USD 3.1 million corresponding to 73% of total, was spent on the output 2.1 and was provided by the zinc smelting companies. Most remarkably, the amount of co-finance at approval stage (= USD 4,000,000) exceeded expectation so that at project closure, a co-finance amount of USD 4,174,000 has been reported (104% of planed).

In addition, the bilateral co-finance from the Government of Norway through the SINOMER II project contributed directly to this project. SINOMER II focusses on concrete measures to reduce the mercury pollution problems through a series of technology assessments and demonstration in combination with support for policy development. Four major sectors regarding mercury pollution were addressed: coal combustion, zinc smelting, mercury mining and industrial use of mercury.

SINOMER II evaluated the fate of mercury in typical zinc smelting processes, estimated emissions from zinc smelters in China, assessed the mercury removal efficiency of existing pollution control devices, and analyzed the cost-benefit of mercury removal technology adopted in the non-ferrous metal smelting sector. Based on the experience from China and the evaluation of mercury control technologies, atmospheric mercury emission control strategies for zinc smelting have been proposed. The outcomes of this project have supported this project directly.

4.9 Project coordination and management

This section evaluates to which extent the national and overall coordination mechanisms have been efficient and effective.

The project coordination, quality control and technical inputs efficiency, timeliness and effectiveness went well. A combination of UNIDO HQ expertise and management supported by UNIDO country office support provided the necessary coordination and contact with the national stakeholders. All reports were provided to the GEF Secretariat on time and at good quality.

4.10 Gender mainstreaming

The project did not include specific gender dimensions; no socioeconomic benefit were identified at the national and local levels.

The project is of technical nature and within the production lines of the enterprises follow the general rules in relation to workers´ health and safety.

This project paid attention to the gender dimensions by paying attention to the potential differences in occupational roles and other social factors.

Among project partners, the majority of staff were female.

4.11 Procurement Issues

This project did not suffer from particular procurement issues. Information in more detail include:

- MEP/FECO is audited on annual basis and at the end of the project for financial performance.
- The evaluation team did not go further into details and submit the overall auditing report as part of its report.
- The universities (three were sub-contracted) have annual internal audits to review projects and funding.
- In addition, external national audits are implemented every 2-3 years. Projects are selected randomly for intensive auditing.
- At MEP/FECO, financial transactions are at the level of Deputy Director General.
- At universities for contracts, R&D Departments expend funds through approval by finance department.
- For all costs the national regulation as to limits were followed.

4.12 Overall rating of project

The independent final evaluation team rated the overall implementation progress (IP) for the project is **satisfactory (S)**. The details can be seen in Table 22 - Overall ratings table. The effective and smooth implementation of this project as found by the evaluation team is consistent with the progress implementation reports (PIRs) prepared by UNIDO and as summarized in Table 21.

The project has completed all of its activities according to the approved project document including the final independent evaluation by one international and one national consultant. The following reports have been completed by MEP/FECO and her subcontractors, subject to final review by the Ministry of Environmental Protection (MEP). These are either self-standing reports or the respective institutions have authored relevant chapters in the final technical report:

1) Current estimated emissions and exposure, as well as existing control technologies in China,
2) International mercury pollution control of zinc smelting industry,
3) Gap analysis of mercury pollution control in China and international zinc smelting industry,
4) Methods for monitoring mercury emissions from Chinese zinc smelting industry,
5) Methods for assessing risk of environment and human health around zinc smelters,
6) Production and management of pilot smelters,
7) Evaluation of Hg removal effect of demonstration project in pilot smelters The BAT/BEP demonstration plans for the pilot smelters, Activity report by Tsinghua University, December 2014
8) Environmental management mechanism and mercury regulation in Chinese zinc smelting industry, Renmin University of China. November 2014

In addition, three technical reports were completed by an international expert to assist MEP/FECO's subcontractors in completing their respective parts in the project and to provide a global view.

1) The report "Review Report - Best Available Technologies and Best Environment Practices (BATs/BEPs) of Mercury Emission Control in the Global Zinc Smelting Sector" by Jozef Pacyna (2013) helped Tsinghua University to assess the current control technologies in the pilot plants and compare them with the national BAT/BEP.
2) "Recommendation Report on the work plan of one zinc smelting pilot plant" by Jozef Pacyna (2013) helped Tsinghua University to complete the plans for the pilot testing at the two smelters.
3) "Review Report - Cost – Benefit Analysis on Best Available Technologies (BATs) and Best Environmental Practices (BEPs) for Chinese authorities" by Jozef Pacyna (2014) helped Renmin University of China to assess national and local mechanisms, including needs and investment opportunities, to support uptake of BAT/BEP applications.

Finally, a final report for the project – dated July 2014 - has been authored and shared with UNIDO, however, only after completion of the final evaluation will the report be finalized and submitted to the GEF. The report has undergone several iterations between the international consultant and MEP/FEO. The main issues were translation related since very often, the various terms did not match and some clarification was requested. Overall, this exchange was very effective and pleasant.

The overall global environmental objectives/development objectives (DO) rating for the project is satisfactory (S). The only deviation from the original implementation matrix were two project extensions at no cost: the original implementation end date was October 2014, however due to slight delays in the pilot demonstrations at the two sites, the project was extended at no additional costs until April 2015. As of the end of April 2015, all project activities have been completed and the preparations for the terminal independent evaluation were initiated. This moved the official project closure/implementation end date at a no-cost extension until 1 December 2015. During the project closure workshop in June 2015 in Beijing, MEP/FECO and their subcontractors presented the results of the project as well as submitted the draft of a final technical report. This report was finalized during the terminal evaluation in collaboration with the international evaluation consultant.

Rating of project objectives and results:

- **Highly satisfactory (HS)**: The project had no shortcomings in the achievement of its objectives, in terms of relevance, effectiveness or efficiency.
- **Satisfactory (S)**: The project had minor shortcomings in the achievement of its objectives, in terms of relevance, effectiveness or efficiency.
- **Moderately satisfactory (MS)**: The project had moderate shortcomings in the achievement of its objectives, in terms of relevance, effectiveness or efficiency.
- **Moderately unsatisfactory (MU)**: The project had significant shortcomings in the achievement of its objectives, in terms of relevance, effectiveness or efficiency.
- **Unsatisfactory (U)**: The project had major shortcomings in the achievement of its objectives, in terms of relevance, effectiveness or efficiency.
- **Highly unsatisfactory (HU)**: The project had severe shortcomings in the achievement of its objectives, in terms of relevance, effectiveness or efficiency.

Rating system for sustainability sub-criteria

On each of the dimensions of sustainability of the project outcomes will be rated as follows:

- **Likely (L)**: There are no risks affecting this dimension of sustainability.
- **Moderately likely (ML)**. There are moderate risks that affect this dimension of sustainability.
- **Moderately unlikely (MU)**: There are significant risks that affect this dimension of sustainability.
- **Unlikely (U)**: There are severe risks that affect this dimension of sustainability.

All other ratings will be on the GEF six point scale:

HS	= Highly satisfactory	Excellent
S	= Satisfactory	Well above average
MS	= Moderately satisfactory	Average
MU	= Moderately unsatisfactory	Below average
U	= Unsatisfactory	Poor
HU	= Highly unsatisfactory	Very poor (appalling)

Table 21: Progress rating during project implementation according to the three PIRs (from UNIDO to GEF secretariat)

Outcomes	Outcomes by Project Component	Indicators	Target Level	Progress To Date (June 2012)	Ranking 2012	Progress To Date (June 2013)	Ranking 2013	Progress To Date (June 2014)	Ranking 2014	Progress To Date (June 2015)	Ranking 2015
Component	Characterization of mercury emissions from the zinc smelting operations in China										
1	FECO created a coordination and monitoring system in mercury management focusing on the zinc smelting sector	Comprehensive data and reports served as baseline for the development of a monitoring plan which is subsequently institutionalized within FECO	Complete characterization of mercury emissions, exposure, and control technologies in China; monitor plan institutionalized	Contractual arrangements between FECO and its national counterparts are underway	HS	in progress	S	in progress (90% complete)	S	complete	S
Component	Demonstrate BAT/BEP in two pilot plants and evaluate cost effectiveness; organize public outreach events and share lessons learned with the zinc industry										
2	BATs/BEPs adopted for cleaner zinc production	Proper management of mercury and adoption of control technologies at zinc production sites; number of sites willing to adopt new technologies and reduce mercury emissions and exposure	At least two successful pilot projects in China are executed; awareness raised over health risks and the importance of appropriate control technologies; decrease in mercury emissions and exposure	Inception workshop was conducted from 12-14 September 2012, therefore implementation for component 2 has not yet begun	HS	in progress	S	in progress (60% complete)	S	complete	S
Component	Develop and promote policy reform to reduce mercury emissions from the zinc smelting industry										
3	FECO developed mercury management policy to facilitate the uptake of BATs/BEPs	National mercury management policy is developed for mercury control in zinc smelting operations	Policy reforms facilitate the uptake of BATs/BEPs in the zinc smelting sector	Inception workshop was conducted 12-14 September 2012; therefore, implementation for component 3 has not yet begun	HS	Not yet begun	S	in progress (40% complete)	S	complete	S
	Overall Global Environment Objective/Development Objectives Rating				HS		S				
	Overall Implementation Progress Rating				HS		S				

Table 22: Overall ratings table

Criterion	Evaluator's summary comments	Evaluator's rating
Attainment of project objectives and results (overall rating) Sub-criteria (below)	All targets were met within budget and small extension of project duration	S
Design	See 4.1	S
Effectiveness	See 4.3, both at national and international levels	HS
Relevance	See 4.2; especially since project started before Minamata Convention text agreed and private sector involvement	HS
Efficiency	See 4.4; tiered strategy plan for BAT concluded; MSP project only	S
Sustainability of project outcomes (overall rating) Sub criteria (below)		ML
Financial risks	See 4.8.2; flexibility with cofinance uses during project implementation	ML
Sociopolitical risks	See 3.3.3.1 and 4.10; highly technical in nature	ML
Institutional framework and governance risks	See 3.3.3 and 4.8	L
Environmental risks	See 4.8	ML
Monitoring and evaluation (overall rating) Sub criteria (below)		S
M&E Design	See 4.8.1	S
M&E Plan Implementation (use for adaptive management)	See 4.8 4.11	S
Budgeting and Funding for M&E activities	See 4.11 and 4.8.2	S
Project Management	See 4.8	S
UNIDO specific ratings		S
Quality at entry / preparation and readiness	See	S
Implementation approach	See 4.1 and 3.3.3; well planned and implemented so that no corrective measures necessary	HS
UNIDO supervision and backstopping	See 3.3.4	S
Overall Rating	Largely, perfect match between implementing and executing agency, managerial and technical competence; timely delivery of international importance	S

5 CONCLUSIONS, RECOMMENDATIONS AND LESSONS LEARNED

5.1 Conclusions

Overall, it can be concluded that this project was successful. It provided a first and initial view on mercury-related issues in one sector of the non-ferrous metals industry. Zinc is one of the most important metals with high demands for refined zinc. Since China is the largest producer and consumer of zinc, a detailed insight into this sector has big value.

At two occasions in the questionnaire, the interim secretariat of the Minamata Convention highlighted that she would be interested in exploring options for cooperation to disseminate experience of BAT/BEP gained in this project to other countries involved in zinc smelting, to assist them in the decision making process in relation to emission reduction.

Given the obligations under the Minamata Convention on Mercury, it would be useful to have an increased international component to ensure outcomes from projects are able to be readily made available to interested stakeholders both regionally and globally. It would be useful to have some communication strategies to assist in this dissemination as part of future projects.

The overall good and very positive evaluation of the project and the successful implementation of the project with concrete results should not imply that the mercury issue in the global zinc production sector is resolved. Whereas the project assessed international solutions for mercury release reduction and developed national BAT/BEP solutions, it has to be taken in mind that this project is a pilot project and that the long-term functioning, efficiency and effectiveness of the proposed measures at technical, economic and political level needs to be seen. Therefore, it is highly recommended to have a follow-up activity beyond this terminal evaluation and official project closure.

5.1.1 Project achievements

The project developed an inventory on emissions of mercury from zinc producing sector and updated it. This leads to the shortfall and the lack of coordination with the UNEP project on mercury emission inventory making but is an important component in the MIA (mercury initial assessment) under the Minamata Convention. Inherent is the need for regular updating.

Capacity and awareness was built in governmental sectors (MEP and EPBs), first data on baseline mercury emissions and reduction potential were generated. These need to be followed up to achieve sustainability and monitor changes with time.

Enterprises established project teams with a view to include other production lines and initiated research and analysis of mercury;

Proposal to review analytical standards and methods for mercury monitoring; (TU submitted to MEP, under revision);

Establish an inventory on emissions of mercury from zinc producing sector and update regularly;

Becoming a party to the Minamata Convention includes implementation of related obligations.

During project implementation, additional co-finance could be leveraged so that at the time of project closure, 126% of the planned co-finance has gone to the project implementation. The additional co-finance was generated inside China and can be attributed to national efforts, mainly from the private sector. In numbers: an additional USD 174,000 was leveraged in addition to the planned USD 4,000,000 (reference, section 3.3.1.4).

It is highly valued that the two companies that served as pilots provided written reports: both in Chinese and in English language versions.

In terms of **approaches for mercury reduction technologies and economic assessment**, a clear preference was given to collaborative or synergistic approaches since (i) only one equipment is necessary to achieve the combined benefit of desulfurization, denitration, and demercurization, and (ii) the technology for desulfurization and denitration is very mature in China and any follow-up can build on these experiences and their presence in respective zinc smelters.

The results from the **pilot testing** at the two plants has also shown that with the collaborative reduction technologies alone, the legal limit values cannot be achieved in the exhaust gas from volatilization kiln and therefore, dedicated mercury removal technologies have to be applied. In order to make them achievable, they must become more economic.

Capacity and awareness was built in governmental sectors (MEP and EPBs), first data on baseline generated with the need to follow-up. In the same way, the enterprises build additional capacities when they established project teams with a view to include other production lines and initiated research and analysis of mercury.

A proposal to review analytical standards and methods for mercury monitoring was submitted by the main partner in this project, Tsinghua University. The standard is under revision presently. Due to its dual role – also a member in the BAT group under the Minamata Convention, it can be hoped that the analytical standard will become a national standard and will have international reputation or replication.

No special financial risks have been identified during the project implementation or the terminal evaluation. The project is based on cost-effective and domestic interventions and technologies, thus, minimizing dependencies from external factors;

The recommendations include a range of very different proposals including financial incentives and environmental benefits to reduce mercury emissions.

Possibilities for development of new BAT technologies are a major trigger for continuation after the project (especially domestic and economic).

The project outcomes will be treated as an important reference for MEP to make policy and standards for mercury control in zinc sector.

5.1.2 Project shortfalls

All partners considered the achievements and outcomes of the project remarkable, efficient and sustainable. The direct relation between this project and the Minamata Convention on Mercury and the expectation that the government of China will ratify the Minamata Convention soon/in the near future may be the most efficient trigger to reduce project shortfalls.

At present – and somewhat in contradiction to the conclusions from interview partners as shown in section 6.2 - from a technical point of view it should be mentioned that not all of the mercury reduction measures that have been successfully tested at the two pilot plants are permanent. Some of them, such as the addition of chemicals which did lead to the development of a national technology was applied only during the measurement period due to financial reasons. The long-term efficiency but before all, the financial aspects needs to be converted into routine operation.

From the project, since designed and approved as a pilot testing, not more than a snapshot can be expected. Such snapshot – fortunately at commercial scale - has been delivered and proven successful. The commitment and the investment of the private sector to reduce mercury emissions in the zinc sector in China is a promising start and should be further supported.

It can be considered a shortfall or disappointment that little of the internationally proven technologies could be implemented or tested in China (see section 3.2.3.1).The main reasons were financial but also limits to technology transfer and access to information were identified. This means that also other developing countries may not have the chance to benefit from other experiences and that at each time, a full development must be undertaken. This will lead to increased investments and "reinventing the wheel"; in addition, not all other zinc producing countries may have the intellectual property at hand to undertake such work. Thus, replicability is at risk.

Study tour: USD 44,000 were spent for a one-week study tour of a Chinese delegation to USA and Canada. Whereas on-site visits can be quite beneficiary and face-to-face discussions are often helpful, the usefulness and effectiveness of such study tours are questionable. Very often, too many expectations are placed on such visits. It has to be taken into account, that Chinese companies are competitors to Western companies nowadays and often are not granted entry into private sector.

5.2 Recommendations

5.2.1 General

The first achievement that baseline data on mercury release and reduction has been generated in a joint effort by the government and the enterprises implies that follow-up activities have to be put in place to stabilize the collaboration, monitor the trends and make interventions as necessary.

Since the project outcomes generated an important reference for MEP to make policy and standards for mercury control in zinc sector, these experiences should be widened-up to include other non-ferrous metal industries, especially lead and copper since these processes also build upon ore concentrates and may encounter the same challenges as the zinc sector. It can be hoped that also the solutions from this project will assist in the development of BAT/BEP in related industries.

5.2.2 Need for improved exchange of information and collaboration

5.2.2.1 Technical issues – Exchange of substantial economic data

The EU BREF documents (reference documents on best available technologies) are very good sources of information on technical issues and their recommendations on BAT and BEP are used as a reference worldwide. Although it is assumed that information on production, trade, disposal, *etc.*, of goods, chemicals and waste is openly available such as through intergovernmental organizations such as the World Bank[17] or the Comtrade[18,d] databases, some information from China is missing. A comparison of Figure 3 in this report and Figure 16 below shows the need for better exchange of information. It is highly recommended that MEP Feco, UNIDO and the BAT/BEP mechanisms under the future Minamata Convention on Mercury collaborate to gather the most actual and complete information as to the economic dimension of zinc production and technologies.

Table 1.14: World production of refined zinc

	Production in 1995 (kt)	Production in 2000 (kt)	Production in 2005 (kt)	Production in 2007 (kt)
China	NA	NA	NA	3700
EU	1999	2016	2034	2160
Canada	720	780	724	802
India	NA	NA	NA	745
Japan	664	654	638	598
US	363	371	350	266
Australia	322	494	457	502
CIS	410	538	608	668
NA: not available				

Figure 16: World production of refined zinc according to European Union BREF [7]

5.2.3 UNIDO

1. To take a more active role in seeking cooperation with other GEF implementing agencies in the country

The recommendation relates especially to projects that are implemented in the same country. Concretely in relation to this mercury zinc project in China, there was a "sister" project "Pilot Project on the Development of Mercury Inventory in China" implemented by UNEP (starting date 2012, original ending date 2012 but still ongoing). The UNEP project belongs to the same GEF V objective "Pilot sound chemicals management and mercury reduction" as the UNIDO project. Both are MSP projects and have the same executing agency, MEP-FECO: Foreign Economic Cooperation Office at the Ministry of Environmental Protection of China. The expected outcome of this UNEP project is to "Strengthen China's capacity for identification of mercury sources and priority actions to address mercury issues under a future global convention". Especially in terms of synergies and complementarity and within the financial restriction that both projects were MSP projects only, a close collaboration would have benefitted both projects.

In addition, the (technical) outcomes and outputs can be easier and more effectively communicated through joint channels. The initiative of ´Delivering as One´ [e] can be one of these mechanisms to be fed. The principal GEF implementing agencies –here: UNIDO and UNEP – are members of the ´Delivering as One´ initiative, and should ensure that the UN initiatives do not only address soft issues but also include concrete application examples and verification. There are no costs involved

[d] UN Comtrade is a repository of official trade statistics and relevant analytical tables. It contains annual trade statistics starting from 1962 and monthly trade statistics since 2010

[e] ´Delivering as One´ is the name of an initiative established by the then UN Secretary-General Kofi Annan in 2005. This effort is mostly led by the group the United Nations Development Group (UNDG), a group of 32 United Nations specialised agencies working on international development issues including the environment.

since these projects are financed and co-financed and it is an obligation by all partners to fill the initiative with content. The GEF projects under the multilateral environment agreements (MEAs) can be good examples.

With this project, the expression ´pilot testing´ has received a new definition, which have not been used by UNIDO and other agencies in the past. So far, the term ´pilot´ referred to either (i) the size/scale of the project such as plants or technologies (*e.g.,* smaller than commercial operation) or (ii) the fact that a project is implemented not at all locations (in China often in a few demonstration provinces but not nation-wide or in a few countries and not worldwide). For both, the option for the upscaling or replicability at different locations were the main objectives. In this project, the time duration was one of the main criteria that define ´pilot´; some of the measures were present only for a single measurement event (see section 4.5).

5.2.4 Government and/or counterpart organizations

2. MEP/FECO to more actively link related projects

Whereas the linkage of projects from different donors but on the same project – such as the Norway funding into the GEF-funded activities –went well, MEP/FECO should have had a more active role to link the UNIDO to the UNEP project. Whereas the collaboration between the responsible staff in MEP/FECO was visible and at the onset of the UNEP project (note: the international evaluation consultant was the project manager for the UNEP project until mid-2015) MEP/FECO introduced the staff and cross-cutting issues were discussed, such exchange was not maintained to the external partners throughout the projects.

Recommendation: MEP/FECO project manager to establish an exchange mechanism between staff at executing agency and with external partners. Costs will be negligible or zero since such exchange and updating can be done electronically. Setting up a "virtual" repository[f] containing contact details and progress reports as well as finalized outputs would also benefit the exchange between implementing and executing agency. The usefulness is greater for the technical content and does not need to contain details on project or finance management.

5.3 Lessons learned

1. Need for broader approach: Some zinc concentrates contain high proportions of lead and these metals are also recovered. Zinc is also associated with cadmium and the concentrates are a source of to recover these metals. As a consequence, production of these metals can also be associated with the release of mercury similar as in the zinc production. It has been shown in this project that the two zinc plants produce many other (refined) metals as well such as gold, silver, indium, copper, cobalt and other rare metals (see section 3.2.4).

2. On the other hand, "co-benefits" with other conventions, for example in relation to emissions of unintentional POPs such as polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) under the Stockholm Convention on Persistent Organic Pollutants (POPs) cannot be derived. Whereas the mercury emissions are mainly associated with the ore processing, *i.e.*, primary zinc production processes, PCDD/PCDF emissions are associated with the secondary ferrous and non-ferrous metal processes, *i.e.*, recycling operations. The raw

[f] Cloud systems exist in various forms. It must be secured that they can be accessed from all countries

materials and the technologies are different. Nevertheless, basic principles of good managerial and operational practices apply.

3. This project has shown that with a view of sustainability, the long-term implications from in-kind co-finance might have been underestimated. For example, the co-finance from Norway provided useful technical and contextual input to the project; however, due to "disturbances" at the political level, Norway dropped out of future aid assistance to China. It can only be hoped that on institutional or personal basis, the established network can be maintained beyond this project for mutual and global benefit.

6 ANNEXES

6.1 Terms of reference

6.1.1 ToRs international evaluation consultant

[refer to document from UNIDO webpage; 46 pages]

6.1.2 ToRs national evaluation consultant

Same ToRs as for the international consultant but for implementation at national level (China) and in a supportive role to the international evaluation consultant. The national consultant, in addition, was responsible for the planning of the site visit, reviewing or translation of project documents existing in Chinese language only, and was a valuable resource for the evaluation team.

6.2 List of interviewees

Organisation	Name	Function
Intergovernmental organizations		
UNIDO	Riccardo Savigliano	Industrial Development Officer, Project manager at final stage of the project; Implementing agency
	Ludovic Benaudaut	Industrial Development Officer, Project manager at initial stage of the project; implementing agency
	Stephan Sicars	Director, Environment Branch, Programme Development and Technical Cooperation Division
	Guillermo Castellá Lorenzo	Unit Chief, Emerging Compliance Regimes Unit, Environment Branch
	Grace Halla	International Consultant to the project manager
	Javier Guarnizo	Senior Evaluation Officer, Office for Independent Evaluation; Office of the Director General
Interim Secretariat of the Minamata Convention	Sheila Logan	Programme officer
GEF Secretariat		Donor
National institutions		
MEP/FECO	Zuguang Wang	Project manager, Mercury Working Group; Executing agency
	Yangzhao Sun	Chief, Minamata Convention (Mercury Working Group?); Executing agency
Hunan EPA	Yuanzhao Li	Environmental Protection Bureau; Cofinance; provincial policy implementation
Sub-contractors		
Tsinghua University	Shuxiao Wang Qingru Wu	Author of technical reports, measurements of mercury concentrations at the two pilot plants, contracted by MEP/FECO
Renmin University	Qianmeng Lu Jieqiong Zhang Muhua Ren	Authors of technical report, contracted by MEP/FECO
University of Science and Technology, Beijing (USTB)	Yongming Wu	Author of technical report of study on zinc smelting sector abroad
Private sector		
Shaanxi Zinc Smelting Co., Shangluo	Zhengmin Wang, Xiaoyang Cui	Beneficiary, cofinancier, pilot plant
Hunan Shui Kou Shan Non-ferrous Metals Group Co., Ltd.	Conghang He Guoliang Hong Zaochun Chen Wei Li Wenzhou Xie Xianbo Tan	Director for Environment, Deputy Plant Manager, Beneficiary, co-financer, pilot plant

6.3 Itinerary – site visit to China

Time		Activities	Note
Monday Nov 16	Morning	Arrival of the Team Leader Heidi Fiedler	
	Afternoon	Fly from Beijing to Changsha	CA1373 12:40-15:10
		Drive from Changsha to Hengyang	16:00-19:00
	Accommodation		Shuikoushan
Tuesday Nov 17	Morning	Meeting with Shuikoushan and local EPBand site visiting	9.00-11.30
	Afternoon	Drive from Hengyang to Changsha airport	12.30-15.30
	Afternoon	Fly from Changsha to Xi'an	MF8235 16.55-18.40
	Evening	Drive from Xi'an to Shangluo	19:30-21:30
		Accommodation	Shangluo
Wedesday Nov 18	Morning	Meeting withShangluoand site visiting	09.00-13.00
	Noon	Drive to Xi'an	13.00-15:30
	Afternoon	Fly to from Xi´an to Beijing	CA1202 17.35-19.35
Thursday Nov 19	Morning	Meeting with FECO	09:00-10:00
		Meeting with Renmin University of China	10:00-12:00
	Afternoon	Meeting with USTB (University of Science and Technology Beijing)	14.00-15.00
		Meeting with Tsinghua University	15.00-17.00
Friday Nov 20	Morning	Team work/reporting	
	Afternoon	De-Briefing at FECO	14.30-15.30 FECO, Tsinghua University, Renmin University of China, University of Science and Technology Beijing
		Visit to laboratory of Tsinghua University	16:30-17:30

6.4 Progamme – International consultant´s mission to UNIDO HQ

Time		Activities	Note
Wednesday March 16	5:55-11:55	Arrival of International consultant in Vienna	ORB-CPH: 5:55-6:55 CPH-VIE 10:10-11:55
		Accommodation	Vienna
Thursday March 17	Morning	Preparation	
	14:30-16:00	Formal presentation of evaluation	UNIDO HQ

Time		Activities	Note
		findings	Meeting room D1232
	Evening	Accommodation	Vienna
Friday March 18	Morning	Meeting withUNIDO EVA	UNIDO HQ
	17:25-22:05	Return from Vienna to Örebro	VIE-CPH 17:25-19:15 CPH-ORB 21:05-22:05

6.5 Documents reviewed

The documents reviewed can be categorized into two broad categories:

1. Documents related to administration and implementation of the project, and
2. Technical reports (often subcontracted) in support of project implementation.

6.5.1 Documents related to administration and implementation of the project including technical reports

Upon contracting the international and national evaluation consultants (September 2015) and following further requests, the following documents/information were provided. The listing is according to the provider of information. The vast majority of the documentation was submitted electronically.

European Union (2014): Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries. Final Draft October 2014

6.5.2 From MEP/FECO

Most documents were provided directly to the international consultant. The documents in Chinese language were provided to the national consultant first and then forwarded to the international consultant.

UNIDO/GEF (2012): Request for CEO Approval "Reduction of mercury emissions and promotion of sound chemical management in zinc smelting operations" (28 pages); Project document for the project as approved by the GEF CEO (4)

MEP/FECO (2015): Report ´Reduction of Mercury Emissions and Promotion of Sound Chemical Management in Zinc Smelting Operations - Final report´. Prepared by MEP/FECO, July 2015 (revised in 2016), for Global Environment Facility—United Nations Industrial Development Organization (6)

China (no date): Emission standard of pollutants for lead and zinc industry. Informal translation

China, Ministry of Industry (2015): 铅锌行业规范条件（最初由发改委于 2007 年发布《铅锌行业准入条件》，后工信部于 2015 年发布《铅锌行业规范条件》代替原有《准入条件》） (EN: The lead and zinc industry standard conditions (originally released in 2007 by the Development and Reform Commission and named "lead and zinc industry access", then the Ministry issued "lead and zinc industry standard conditions" in 2015 instead of the original "access")

Shangluo (2015): 陕西锌业有限公司试点报告. 陕西锌业有限公司, 2015 年 8 月 (EN: Pollution control situation in Shaanxi Zinc Industrial Co., Ltd, August 2015)

Shuikoushan (2015): 全球环境基金. 锌冶炼行业汞污染减排与无害化管理项目. 汞污染控制及减排能力建设成果报告. 湖南水口山有色金属集团有限公司.2015 年 4 月 29 日 (EN: Report on the Pollution control of mercury and capacity building of Shuikoushan Nonferrous Engineering Co., Ltd, April 29, 2015)

Shuikoushan progress reports (9) (2012-2015): 湖南水口山有色金属集团有限公司四厂. 锌沸腾炉系统制酸废水微循环利用工程. 技术方案. 衡阳水口山有色工程设计有限公司 (EN: technical scheme on the waste water recycling project of Hunan Shuikoushan Nonferrous Engineering Co., Ltd)

6.5.3 From UNIDO

UNIDO/GEF (2012): Request for CEO Approval “Reduction of mercury emissions and promotion of sound chemical management in zinc smelting operations” (28 pages); GEF ID 4816;

UNIDO (2015): Terms of Reference Independent Terminal Evaluation of the UNIDO Project “Reduction of mercury emissions and promotion of sound chemical management in zinc smelting operations“. Project Number: GEF/CRP/12/001; SAP ID: 100338; URL: http://www.unido.org/fileadmin/user_media_upgrade/Resources/Evaluation/CPR_GEFCRP12001_TE_ReductionHgEmissions_TOR_Final_140313.pdf

UNIDO (2012): UNIDO contract No. 16002611 to MEP/FECO for “Project No. GF/CPR/12/001 – Reduction of Mercury Emissions and Promotion of Sound Chemical Management in Zinc Smelting Operations”

MEP/FECO (continuous): Annual Report for UNIDO Project no.GF/CPR/12/001 “Reduction of Mercury Emissions and Promotion of Sound Chemical Management in Zinc Smelting Operations”

- Annual report 2013.Reporting Period: January 2013 – December 2013.Report by MEP/FECO to UNIDO (Water Management Unit).Date of submission: April 15, 2014
- Annual Report 2014.Reporting Period: January 2014 – December 2014.Report by MEP/FECO to UNIDO (Water Management Unit).Date of submission: March 13, 2015
- Annual Report 2015.Reporting period: January 2015 – June 2015.Report by MEP/FECO to UNIDO (Water Management Unit).Date of submission December 2015

UNIDO (continuous): UNIDO Annual Project Implementation Report (PIR)

- Fiscal year (FY) 2012 (1 July 2012 – 30 June 2013) - 31 October 2012
- Fiscal Year (FY) 2013 (1 July 2012 – 30 June 2013) – 8 October 2013
- Fiscal Year (FY) 2014 (1 July 2014-30 June 2015) – 14 November 2015

Invoices from MEP/FECO to UNIDO requesting the payment of the installments as laid down in the contract between UNIDO and MEP/FECO [11]:

- Invoice, April 11, 2013: Second disbursement of USD 250,000
  Management fee of USD 12,000 (included fee for 1st disbursement)
- Invoice, July 21, 2014: Third disbursement of USD 250,000
  Management fee of USD 7,500

- Invoice, March 2, 2015: Fourth disbursement of USD 210,000
  Management fee of USD 6,500
- Invoice, May 28, 2015: Fifth and final disbursement of USD 101,165
  Management fee of USD 3,035.

MEP/FECO (continuous):Quarterly progress reports. Prepared by MEP/FECO to UNIDO. Periods covered:

- 1 October 2012-31 March 2013
- 1 April 2013-30 June 2013
- 1 July 2013-30 September 2013
- 1 October 2013-31 December 2013
- 1 January 2014-31 March 2014
- 1 April 2014-30 June 2014
- 1 July 2014-30 September 2014
- 1 October 2014-31 December 2014
- 1 January 2015-30 June 2015 (summary)

Jozef M. Pacyna (2013): Review Report - Best Available Technologies (BATs) and Best Environment Practices (BEPs) for mercury emission control in the global Zn smelting sector. Annex 1 July 2013

Jozef M. Pacyna (20xx): Recommendation Report on the work plan of one zinc smelting pilot plant. Annex 1

Jozef M. Pacyna (2014): Review Report - Cost – Benefit Analysis on Best Available Technologies (BATs) and Best Environmental Practices (BEPs) for Chinese authorities. April 2014

Tsinghua University (2014): Activity Report: Evaluation of Hg removal effect of demonstration project in pilot smelters. December 2014

Renmin University of China (2014): Environmental Management Mechanism and Mercury Regulation in China Zinc Smelting Industry.Nov.2014

6.6 Summary of project identification

See section 3.3.1.4 - The financial details at project conclusions are summarized in Table 10and Table 11.

Table 10: Summary of committed/planned and actual finance reports for GEF funds and co-finance (USD)

Project component	Activity type	GEF Financing (in USD)		Co-financing (in USD)	
		Approved	Actual	Promised	Actual
1 Characterization of Hg emissions from Zn smelting	a, b	300,000	326,725	900,000	640,000
2 Demonstration of BAT/BEP	a, b	450,000	464,000	2,490,000	3,280,000
3 Policy reform in Zn smelting industry	a, b	150,000	170,440	250,000	254,000
6. Project management		90,000	28,835	360,000	50,000
Total		**990,000**	**990,000**	**4,000,000**	**4,224,000**

Table 11: Summary of expected and actual co-finance (USD)

Source of co-financing	Type	Project preparation		Project implementation (USD		Total (USD	
		Expected	Actual	Expected	Actual	Expected	Actual
Host gov't contribution	in-kind	N/A	N/A	250,000	195,000	250,000	195,000
Host gov't contrib-ution, activities	in-kind				96,000	-	96,000
GEF Agency (ies)	Grant	N/A	N/A	50,000	50,000	50,000	50,000
Bilateral aid agency (ies)	Grant	N/A	N/A	500,000	500,000	500,000	500,000
Private sector	in-kind	N/A	N/A	2,400,000	2,756,000	2,400,000	2,756,000
Academia	in-kind	N/A	N/A	-	441,000	-	441,000
Local government	in-kind	N/A	N/A	800,000	186,000	800,000	186,000
Total co-financing		-	-	4,000,000	4,224,000	4,000,000	4,224,000

Project objectives and structure

6.7 Financial data

See section 3.3.1.4Project costs and co-financing

7 REFERENCES

[1] GEF (2008): Guidelines for GEF Agencies in Conducting Terminal Evaluations. Evaluation Document No. 3. Evaluation Office Global Environment Facility.

[2] GEF (2010): The GEF Monitoring and Evaluation Policy 2010. Evaluation Document November 2010, No. 4. Global Environment Facility Evaluation Office

[3] GEF (2007): GEF Evaluation Office Ethical Guidelines. Evaluation Document No. 2. Evaluation Office Global Environment Facility

[4] UNIDO/GEF (2012): Request for CEO Approval “Reduction of mercury emissions and promotion of sound chemical management in zinc smelting operations” (28 pages); GEF ID 4816; URL: https://www.thegef.org/gef/gef_projects_funding

[5] UNIDO (2015): Terms of Reference Independent Terminal Evaluation of the UNIDO Project “Reduction of mercury emissions and promotion of sound chemical management in zinc smelting operations“. Project Number: GEF/CRP/12/001; SAP ID: 100338; URL: http://www.unido.org/fileadmin/user_media_upgrade/Resources/Evaluation/CPR_GEFCRP12001_TE_ReductionHgEmissions_TOR_Final_140313.pdf

[6] MEP/FECO (2015): Report ´Reduction of Mercury Emissions and Promotion of Sound Chemical Management in Zinc Smelting Operations - Final report´. Prepared by MEP/FECO, July 2015 (revised in 2016), for Global Environment Facility—United Nations Industrial Development Organization

[7] European Union (2014): Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries. Final Draft October 2014

[8] Ministry of Environmental Protection (2010): Emission standard of pollutants for lead and zinc industry. GB 25466; effective as of Oct.1, 2010

[9] Tsinghua University (2014): Activity Report “Evaluation of Hg removal effect of demonstration project in pilot smelters”, December, 2014

[10] Government of Norway (no date): SINOMER II “Sino-Norwegian Cooperative Project on Mercury - Capacity building for reducing mercury pollution“

[11] UNIDO (2012): UNIDO contract No. 16002611 to MEP/FECO for “Project No. GF/CPR/12/001 – Reduction of Mercury Emissions and Promotion of Sound Chemical Management in Zinc Smelting Operations”

[12] UNIDO (2015): UNIDO Annual Project Implementation Report for the period 1 July 2014 until 30 June 2015

[13] Global Environment Facility (2011): GEF 5 Focal area strategies – Chemicals. January 2011. https://www.thegef.org/gef/sites/thegef.org/files/documents/document/GEF-5_POPs_strategy.pdf

[14] MEP/FECO (continuous): Quarterly progress reports. Prepared by MEP/FECO and submitted to UNIDO

[15] MEP/FECO (continuous): Annual report. Prepared by MEP/FECO and submitted to UNIDO

[16] UNIDO (continuous): UNIDO Annual Project Implementation Report (PIR). Prepared by UNIDO to GEF Secretariat

[17] World Bank (no date): Data published by World Bank. http://data.worldbank.org/

[18] Comtrade (no date): UNComtradeDatabase. http://comtrade.un.org/