DATA COLLECTION AND CONFIRMATION STUDY ON THE MINE ENVIRONMENT AND SAFETY IN THE AFRICAN AREA

FINAL REPORT

March 2014

Japan International Cooperation Agency（JICA）

Mitsubishi Materials Techno Corporation

Sumiko Resources Exploration & Development Co.,Ltd.

PREFACE

This Interim Report is to inform progress situation in the “Data Collection and Confirmation Study on the Mine Environment and Safety in the African Area” (herein-after called “the Study”). Objectives of the Study consist of 1) compilation of existing condition and data collection on the mine environment and safety, 2) examination of information on the superiority of mine environmental technology owned by Japanese companies and organizations and to be usable to objective countries, and 3) investigation of the request on capacity development and personnel training. The works of the Study started on October in 2013 based on the contract for the Scope of Works (SW) between the JICA and Joint Venture on the date of October 10, 2013.

This Interim Report contains results of the Preparation Work in Japan and First Site Investigation, which were mainly collected information and data on the mine environment and safety of the objective countries, and this report also provides the priority of investigation sites for mine pollution during the Second Site Investigation.

The experts engaged in period of the Study were the following 4 persons:

1	Team leader/Mine environment A	Kajima Mikio	(MMTEC)
2	Mine safety/Mining engineer B	Yokoyama Takayuki	(MMTEC)
3	Mining engineer A/ Mine environment B	Negishi Yoshimitu	(MMTEC)
4	Geology/Geochemistry/Remote sensing	Kobayashi Hirohisa	(SRED)

Remarks: MMTEC : Mitsubishi Materials Techno Corporation

SRED : Sumitomo Resources Exploration & Development Co., Ltd.

We would like to thank all the concerned persons of the offices related to the mine environment and safety in the objective countries, including Angola, Zambia, Malawi, Botswana, Zimbabwe, Mozambique and South Africa for their kind cooperation.

March 2014

ABSTRACT

(1) Summary of the Study

- Objectives of the Study consist of 1) compilation of existing condition and data collection on the mine environment and safety, 2) examination of information on the superiority of mine environmental technology owned by Japanese companies and organizations and to be usable to objective countries, and 3) investigation of the request on capacity development and personnel training.
- The objective countries consist of eight countries including Angola, Zambia, Malawi, Botswana, Zimbabwe, Mozambique, Madagascar and South Africa.
- The Study is composed of five steps, namely the Preparation work in Japan, First Site Investigation, Analysis work in Japan, Second Site Investigation and Compiling work in Japan.
- The First Site Investigation, consisting of collecting data and information on the mine environment and safety, holding of Seminar, request of the personnel training of each country, was carried out in one month between November 11, 2013 and December 8, 2013.
- Malawi and Zambia were selected as places for Second Site Investigation by consideration work in Japan after the First Site Investigation. The sites consist of three coal mines and small-scale mine for gems in Malawi, and two copper mines and one abandoned zinc-lead mine in Zambia. Finally, actual number of the objective sites reached eight sites.
- The Second Site Investigation was conducted i) environment investigation, ii) soil sampling and analysis, iii) water sampling and analysis, iv) simple survey, and v) inspection for occurrence of pollution, scale of the pollution, mine environment, arrangement of issues, consideration of countermeasure of mine pollution control and current situation about mine environment and safety.
- After the Second Site Investigation, comprehensive work was carried out to extract issues, to integrate information and to recommend several support projects for the future.

Based on the collecting information during site investigations, current situations in respect of mine environment and safety for objective countries are summarized as follows;

(Mine Management and Legislation related to the Mine Environment)

- Each country had newly instituted or revised in 1990’s to 2000’s in order to aim a promotion of mining development as well as a sustainable development of mineral exploration and exploitation of minerals.
- mining policies were shifted from mining depend on only specified minerals such as Au, diamond, etc. to the mineral exploration and exploitation of various kinds of mineral resources such as base metals, rare earth elements (REE) and energy resources (petroleum, natural gas and coal).
- Several countries and areas still have problems of infrastructure building for the mine development and occur difficult to promote a foreign investment for the mineral exploration and exploitation.

(Mining Condition)

- In South Africa, Zimbabwe and Zambia, various kinds of mineral resources has been historically developed for a long time.
- In other countries, the development of mineral resources was relatively recent and further mineral exploration and mine development are expected because of high potential of mineral resources. Particularly, active mineral exploration and a few copper mines have been developed in the southwestward extension areas from the Copper Belt, located along the boundary between Zambia and Democratic Republic of the Congo, in Angola and Botswana (called as Kalahari Copper Belt).

(Environmental Policy and Environmental Condition)

- The environmental legislation, including Environmental (Basic) Law, Environmental Protection Act, etc., has mostly instituted in each country. The environmental impact assessment is mostly regulated within the Environmental (Basic) Law, and the Ministry of Environment is enforced to formulate the environmental policy.
- The evaluation of environmental impact assessment concerning the mineral exploration and exploitation in the Ministry of Environment of the objective countries are entrusted to the ministry in charge of mining. However, staff in charge of environmental evaluation concerning the mining in each country are luck of practical experiences, therefore it is necessary to formulate and enforce a long-term personnel training.
- Concerning the environmental protection such as an environmental management and monitoring plans, project enforcement person in most of countries has a responsible to carry out the environmental obligation according to the Mining Law. However, monitoring enforcement system in whole area of each country is not built yet, thus environmental condition including environmental pollution, hot spots, etc. in each objective country is not comprehended yet.
- Environmental standards for air quality, water quality, soil quality, noise and vibration, etc. had mostly set up in objective countries, however a few environmental items are not set up in some countries. Therefore, it is necessary fully to install the environmental standards for the environmental evaluation.

(Mine Pollution, its Potential and Measures)

- Mine development of sulfide ore deposits such as base metals is rare in Angola, Malawi and Mozambique, therefore ore pollution is presently not found in these areas. However, those areas have also potential of mine pollution.
- Other countries can be found mine pollutions such as acidic wastewater from mine sites, exhaust gas from smelters, etc. and much influence to the environment downwards. However, the environmental investigation and mitigation against the mine pollution is inefficient.
- It is necessary to carry out environmental investigation by monitoring for understanding the environmental condition and formulate the technical guidelines, etc. for countermeasures and those enforcement.

(Chemical Analysis)

- Public laboratory under the ministry related to the environment or mining is not established in Angola and Mozambique, but under consideration. In other countries, the public laboratory is established under the Geological Survey or Ministry of Environment.
- Concerning the analytical accuracy and components, the laboratory related to the Environment

mostly aims environmental analysis, and the laboratory related to the Geological Survey mostly aims environmental analysis purposes to analyze ore mineral, geochemical exploration and inorganic analysis.

- The Laboratory under the Environmental Management Agency in Zimbabwe carries out monitoring investigation and is planning to establish database of analytical results.

(Mine Safety)

- Statistic on disaster and accident in mines and smelters had been obtained in Botswana and Zimbabwe, but those of other countries was not obtained.
- Concerning the mine safety, ministry and government agency in charge of each country are supervising operating mines such as ministerial direction, order, etc. without practical training for the mine safety. However, technical training of mine safety is periodically enforced by the Chamber of Mines in Zimbabwe.

(Personnel Training and Request of Technical Training)

- Each country has not specified personnel training program.
- Requests from relevant ministries and agencies of each country to JICA are covered a wide range of categories, many persons and various period of training.

(2) Recommendations

On the basis of challenges in the each country that were obtained information relating to mine environment and safety during study, recommended supports in eight countries and plans for improvement and countermeasure in Zambia and Malawi were described in the Chapter 5.

Based on collected information by this study, the current aspects of mining sectors in objective countries are divided into three situations as follows;

i) Resources country or country of relatively developed within mineral resources production (South Africa, Angola, Botswana, Zambia and Zimbabwe)
ii) Developing country within mineral resources production (Malawi and Madagascar)
iii) Country standing midway between relatively developed country and developing country within the mineral resources production (Mozambique)

Among these, countries belonging to the above i) have specific concerns and challenges on mine environment and safety, which immediate countermeasures or handling are required. On the other hand, countries belonging to ii) and iii) do not have critical issues in respect of mine environment and safety, however the countries are needed for preparation about to improve laws and to upgrade skills for person in charge for the future. In addition, Madagascar is thought to be belonging to the ii), which the country has large-scale mines such as Amvatovy Nickel Mine and Mandena Ilmenite Mine. However, their current stand relating to mine environment and safety as an audit side are assumed as unstable situation due to lack of their standards in respect of the permission works.

Based on the above situations in the objective countries, future projects are proposed as follows;

(Zambia)

Program: Construction work for countermeasure of mine pollution at around Kabwe Abandoned Zinc-Lead Mine

- Situation relating to the countermeasure: Zinc and lead contents of water and soil in river, drainage and ground around the former mine show high. The former tailing dam was basically backfilled by slag and waste of previous mine. These residual materials are easy to flow out under the influence of erosional and wind process. Zinc and lead contents of water and soil around former mine and along the downstream show high content. Based on this situation, these components have a probability of diffusion to around the former mine already. Additionally, there are no protection fence around the former mine lots, inhabitants are easily able to inter the area. For the former mine water flowing around former mine, inhabitants have been used for domestic use water in the downstream. The area to be needed for the countermeasure is approximately 2km x 2km.
- Content of the countermeasure: The countermeasure items are grading, replanting and installation of protection fence at the former dumps, construction of sediment pond, and construction of drainage canals at downstream. Contamination concerns will be reduced by the countermeasures and the related organization will be able to manage the pollution in the future. If these countermeasures will be commenced the constructions, the works should be proceeded to take a step-by-step approach due to the scale of the countermeasure works are comprised of small and large scale. Among these, construction work of the sediment dam corresponds to the biggest scale in the works. For such reason, comprehensive countermeasure plan is needed to being before the work. Prospective time frames of the construction works are 4-5 years for sediment dam, 2-3 years for drainage canal and 1-2 years for others. The budget scales for the constructions are estimated as dozens of hundred million yen in total, dozens of million to hundreds of million yen for the sediment dam, hundreds of million yen for the drainage canal and tens of million to hundreds of million yen for the other constructions.

  Clarification of the pollution mechanism is needed for above construction work before the commencement. For the interpretation, analysis for soil and water by boring survey and simulation for groundwater flow are needed for the clarification. The budget scales for the clarifications are estimated as approximately tens of million yen.
- Conducting of training: Site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

  Additionally, abandoned Sado Au Mine and Ashio Cu Mine are recommended as visiting sites for to learn the knowledge how to utilize abandoned mine. These abandoned mines have tourist facilities and scenic parks as a recreational facility for public.

Program: Construction work for improvement of drainage water from mine facilities at Mopani and Konkola Mine in Copperbelt

- Situation relating to the improvement: Metal contents of water and soil in river, drainage and ground around each mine show a little bit high in part of the site. Also seepages from the tailing dam of each mine are observed in near the dam, which these seepages are directly flowed in the river. Among this, water quality from water well at near the dam of Konkola Mine shows acidic feature in the pH. Inhabitants near the well have been using the water as a domestic use water. The area to be needed for the countermeasure is approximately 2km x 2km.
- Content of the improvement: Upgrade and new construction for the drainage canals around mine facilities and tailing dam are needed for the improvement. The improvement also needs groundwater flow analysis before the upgrading.

  Prospective time frames of the improvement works are 2 years for the drainage canals and 3-4 years for the new construction. The budget scales for the constructions are estimated as hundreds of million yen or tens of million yen for the improvement and hundreds of million yen for the new construction.

  For the groundwater analysis, analysis for soil and water by boring survey and simulation for groundwater flow are needed for the clarification. Prospective time frame of the work will be taken 2 years. The budget scales for the clarifications are estimated as approximately tens of million yen.
- Conducting of training: Site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

  Additionally, abandoned Sado Au Mine and Ashio Cu Mine are recommended as visiting sites for to learn the knowledge how to utilize abandoned mine. These abandoned mines have tourist facilities and scenic parks as a recreational facility for public.

Program: Country-by-Country training for countermeasure construction in respect of mine environment

- Background of the training: Mining development in Zambia has been very active. On the other hand, there are concerns about improvement and countermeasure relating to the mine environment and the related persons are well understanding this situation. However, the improvement and construction works are still not quite advanced enough yet at the moment. For example, rehabilitation plan for the Kabwe abandoned mine has not commenced the construction works so far.

  For above situation, participation of parsons in charge to the training is useful for considerations about the sustainable mining in the country.

- Conducting of training: Site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

  Additionally, abandoned Sado Au Mine and Ashio Cu Mine are recommended as visiting sites for to learn the knowledge how to utilize abandoned mine. These abandoned mines have tourist facilities and scenic parks as a recreational facility for public.

(Malawi)

<u>Program</u>: Training and construction work for countermeasure at Mchenga Coal Mine

- Situation relating to the countermeasure: Acid mine water has flowed from in the stream and collapses of the ground are also observed on the pit. These features are concerned about to occur landslides including acid water during heavy rain and rain season. Settlements locate in downstream of the same catchment. For this, if the landslide happened from the concerned site, the slide is able to occur disaster. The area to be needed for the countermeasure is approximately hundreds of meter x meter.
- Content of the countermeasure: Construction work to improve outflows of acid mine water and prevention of the collapse of ground are needed for the countermeasure. The items of the actual work consist of construction of discharge canal, protection dike and slope protection, and land-cleaning and grading, and so on. In the training, countermeasure construction will be carried out during the training and the lectures instruct the method of countermeasures and construction management as well.

  Both construction for outflow prevention of mine water and collapse of the ground are needed for the countermeasure. Time flame will be taken 2 or 3 years and the budget scale estimated at a hundred million yen.
- Conducting of training: Site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

<u>Program</u>: Training and improvement work of mine safety at Mchenga Coal Mine

- Situation relating to the improvement: Space in the pit has basically 3m x 2.5m and the width of the pit becomes narrow at the deeper part in the pit. Belt conveyor is used for the transport of coal from face in the pit. However, the space between walkway and belt conveyer is not enough for the operation due to the narrow in the pit. Accident contact with the belt conveyer and worker is easy to occur in the place. Additionally, rock fallings are easy to occur in the pit situation where there are no enough poling boards under the roof. Based on the above, area for the improvement covers main pit and mine facilities.

- Content of the improvement: The items consist of technical guidance, and countermeasure construction in respect of the space use and rock falling protection in the pit. Among these, designing of layout for the pit space and set of pillars and poling boards are needed for the improvement. In the training, improvement construction will be carried out during the training and the lectures instruct the method of improvement and construction management as well.

  Time flame for the improvement construction will be taken 2 or 3 years and the budget scale estimated at tens of million or a hundred million yen.

- Conducting of training: Training in respect of safety are needed to be held in the site and Lilongwe, which experts having experience of management at coal mine should be dispatched from Japan as lecturers. Based on this, related persons are able to obtain knowledge and method of management relating to upgrading of the technologies of mine safety.

(Madagascar)

<u>Program</u>: Acquisition of techniques for audit and monitoring of mine environment and safety

- Situation relating to the acquisition: Related persons in the government side have been suggesting that existing laws in respect of mine environment and safety are not corresponded to actual situation in the related terrain of the recent date, which there are no original standards for effluences. On the other hand, there are no manuals for method of the audit and monitoring to preserve related laws. Among these situations, judgments by audit side have became unstable on processes for related permission such as EIA. The situation are especially noticeable in the case of large-scale mines and the facilities, which mines were commenced their operation in recent years.

- Conducting of training: The acquisitions by training are performed in Japan. Items of the training consist of basics of mine environment and safety, standards of environment and safety relating to audit and monitoring, and method and procedure of audit and monitoring. Additionally, site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

  Besides the above, Hishikari Au Mine, Naoshima Cu Smelter and Hhuga Ni Smelter as actual operating metal mine and facilities are recommended as visit sites, which related trainees are able to obtain basic knowledge of mining.

Program: Support for upgrading of related laws in respect of mine environment and safety

- Situation relating to the upgrading: As noted above, related persons in the government side have been suggesting that existing laws in respect of mine environment and safety are not corresponded to actual situation in the related terrain of the recent date, which there are no original standards for effluences. On the other hand, there are no manuals for method of the audit and monitoring to preserve related laws. Among these situations, judgments by audit side have became unstable on processes for related permission such as EIA. The situation are especially noticeable in the case of large-scale mines and the facilities, which mines were commenced their operation in recent years. Ministry of Mines and National Office of Environment are well recognized need to upgrade as audit side. Among these, Directorate of Mines has requested the upgrading of related laws and procedures to this study.
- Content of support: This program supports to revisions of laws relating to current mining and environmental laws and creations of procedures relating to audit and monitoring. I this program, revisions of laws and regulations with consideration for the management of mine closure, revisions of standards for related matters, and upgrading for current audit and monitoring are included in the support.

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(Photographs)

LIST OF ABBREVIATIONS

BEE	Broad-Based Black Economic Empowerment
EIA	Environmental Impact Accessment
EU	European Union
GIS	Geographical Information System
HIDA	The Overseas Human Resources and Industry Development Association
JICA	Japan International Cooperation Agency
JOGMEC	Japan Oil, Gas and Metals National Corporation
SADC	Southern African Development Community
UNEP	United Nations Environmental Program
WHO	World Health Organization
ZCCM	Zambia Consolidated Copper Mines Limited
ZEMA	Zambia Environmental Management Agency

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Mineral resources are indispensable for the promotion of industrial and economical activities. They are highly important for supporting future development of economies, including that of developing countries. Development of mines would have strong effects on economies and societies. It will contribute to industrial development, enhance infrastructure and develop human resources, for example, engineers and technicians, even in remote regions. For these reasons and more, many of the developing countries have a high potential of utilizing their own mineral resources effectively.

However, development of mines is expensive and demand costly technologies from the initial stages of mineral exploration to exploitation to mine operation. The process is also accompanied by many difficulties and hazards including environmental concerns and issues. Accidents have occurred at mines due to defects in mine safety measures, and deficiencies in the management and legislative system, leading to loss of lives and decrease in operational efficiency. For these reasons, it is vital to reduce the occurrence of accidents by improving management system for mine safety and the working environment. It is essential that environmental issues are taken into consideration from the start to the end of mining process to ensure sustainable mine development. This includes and is not limited to, environmental contamination due to wastes, tailing, exhaust smoke, wastewater drainage and improper control and/or management after mine closure.

Many African nations have high potential for existing mineral resources, however, many of these countries have no or incomplete legislative, measures and management system regarding mines, environment, and safety. Under these backgrounds, Japan-Africa Ministerial Meeting for Resources Development was held on May, 2013 and declared “Japan-Africa Promotion Initiative for Development of Resources” upon discussions on the promotion for investment of resources, preparation of infrastructure, strengthening the foundation of resource industries and development of human resources, sustainable development of mineral resources on the mine environment and safety, as well as co-existing with regional societies.

Details of “Japan-Africa Promotion Initiative for Development of Resources” declaration are as shown below:

1) To promote for investment on resource development and for the preparation of infrastructures,
2) To strengthen the foundation for resource industries and development of human resources,
3) To perform sustainable development of resources in the mining environment and safety, and,
4) To co-exist with regional societies.

1.2 Purpose of the Study

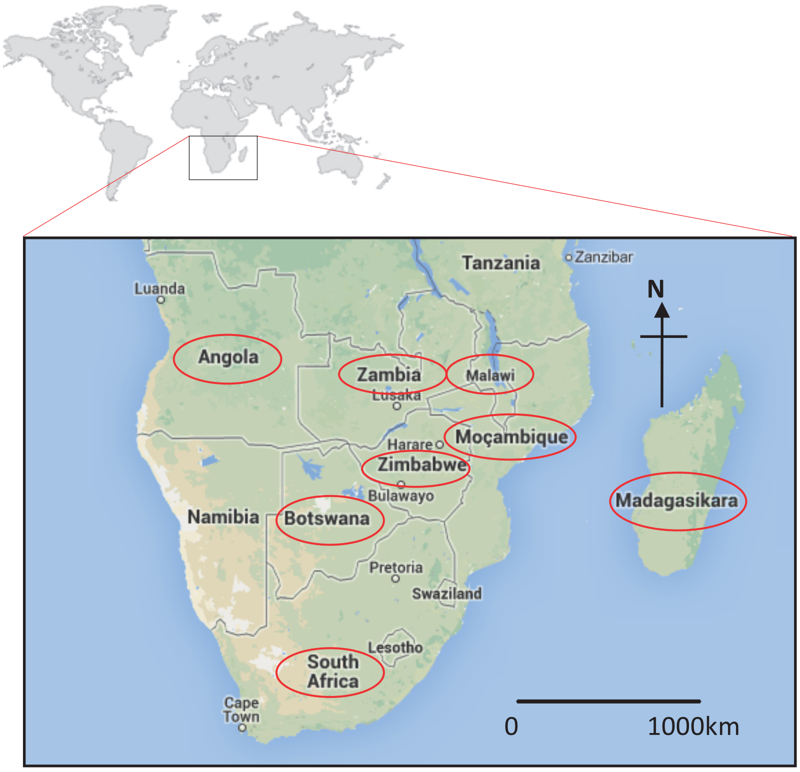
This investigation is to be carried out keeping in mind the mine environment and safety. The objectives of the Study are as follows:

1) Review and arrange available information and data in the present state and to collect and review further specific information and data,
2) Collect and review information and data in regards to the superiority of technologies being possessed by Japanese enterprises and/or organization, which are utilizable in the country subject to the investigation, and
3) Investigate the demand of capacity building and the development of human resources from related organizations in the specific country of the Study.

The results of the above objectives will be used to create the guidelines required for the determination of support from JICA in order to carry out sustainable mine development with due considerations of the environment and in accordance with the state of developing countries in Africa.

1.3 The Study Area

The eight countries that are part of this Study are Angola, Botswana, Madagascar, Malawi, Mozambique, South Africa, Zambia, and Zimbabwe. All the countries are located in the southern part of Africa (Figure 1.1).



(Map image, Google)

Figure 1.1 Map of southern Africa showing countries that are part of this Study, circled in red

1.4 Work Details of the Study

The Study was carried out for six months from October, 2013 to March, 2014. The work that carried out in this timeframe were : 1) Preparation work in Japan, 2) First Site Investigation, 3) Work in Japan, 4) Second Site Investigation and 5) Reviews and discussions in Japan, further detailed in Table 1.1 below.

Table 1.1 Work Details of the Study

Investigation Step	Period	Items to be Investigated	Remarks
1. Preparation in Japan	10 Oct – 9 Nov, 2013	(1) Preparation and review of investigation plan (2) Collection/review of existing information and data (3) Preparation of questionnaire and sending it to the countries that are part of this Study (4) Systematic arrangement of issues on mine environment/safety (preparation and review of items to be presented at the seminar)	-Work in Japan -Questionnaire -Items to be presented at seminar
2. First Site Investigation	10 Nov – 8 Dec, 2013	(1) Collection/review information/data on: a. Policy, legislative system and management system in regard to mine environment and safety b. The number and types of mines and the state of operation c. Existing issues on mine environment, and kinds/states of issues, if any d. Existing issues on mine safety, and kinds/states of issues, if any (2) Seminar to be held (3) Confirmation on demand for development of human resources from the relevant organization in country of study	-Collection of questionnaire -Collection of information and data -Seminar -Demand for human resource developing -Report at site
3. Work in Japan	9 Dec, 2013 – 17Jan, 2014	(1) Analysis of answers to questionnaire and selection of the country to be subject to the Second Site Investigation (2) Preparation and submitting of Interim Report (IT-R)	-Analysis of questionnaire -Selection of the country for the Second Site Investigation -Interim Report
4. Second Site Investigation	18 Jan – 2 Mar, 2014	(1) Mine site survey (2) Sampling and analysis of soil (3) Sampling and analysis of water (4) Summary survey (5) Report on site investigation and discussions	-Collection of information -Report of Second Site Investigation -Report at site
5. Review and Discussion in Japan	3 Mar – 19 Mar, 2014	(1) Analysis on results of site investigation and evaluation on the same (2) Holding of seminar in Japan (3) Preparation, explanation and discussions on the Draft Final Report (D-FR) (4) Preparation and submitting of Final Report (FR)	-Seminar in Japan -Draft of Final Report -Final Report

1.5 Work Flow and Procedures of the Study

Work flow chart of this investigation is presented in Figure 1.2.

1.6 Work Schedule of the Study

The planned schedule of the Study is given in Figure 1.3.

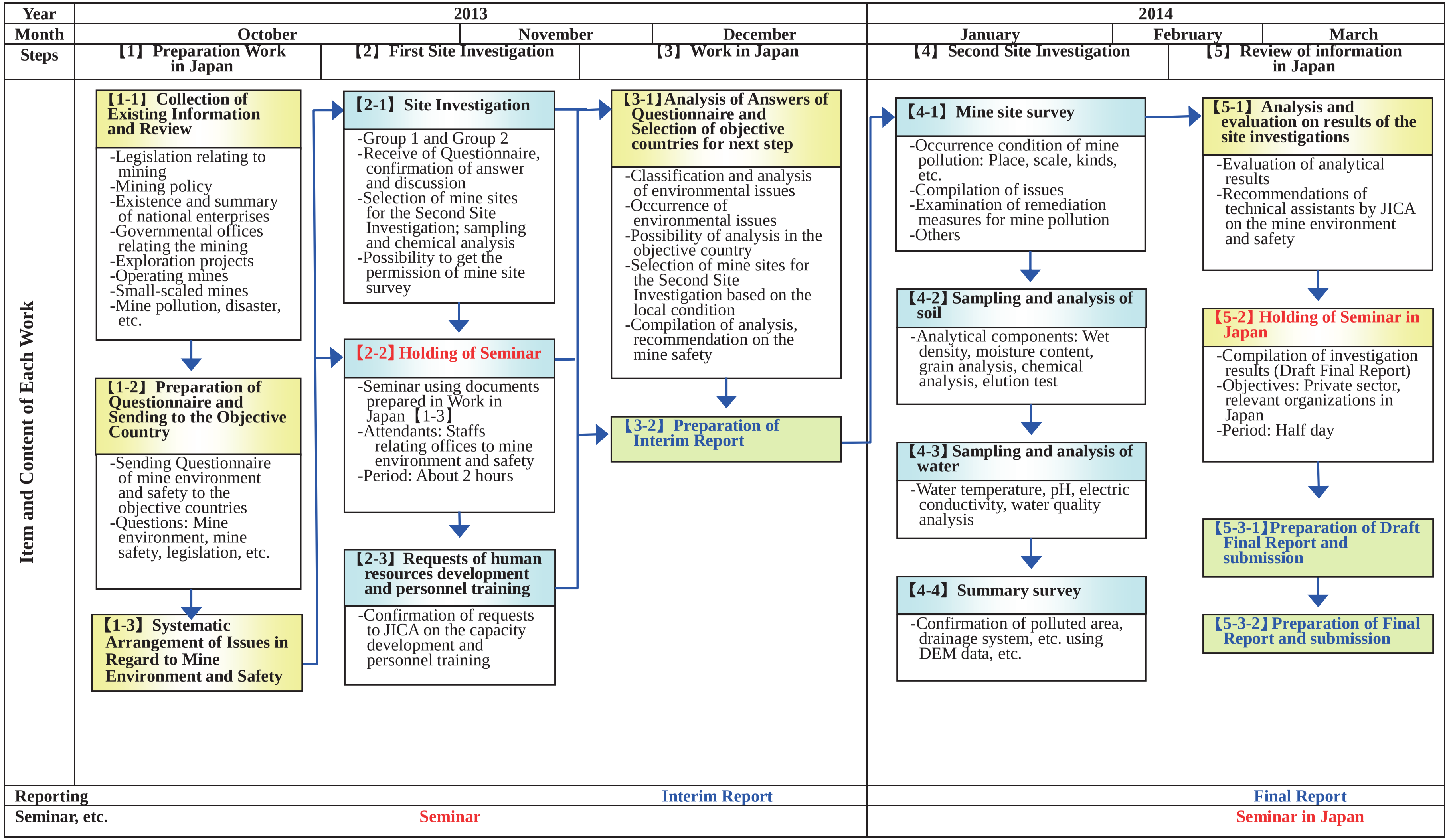


Figure 1.2 Work Flow Chart of the Study

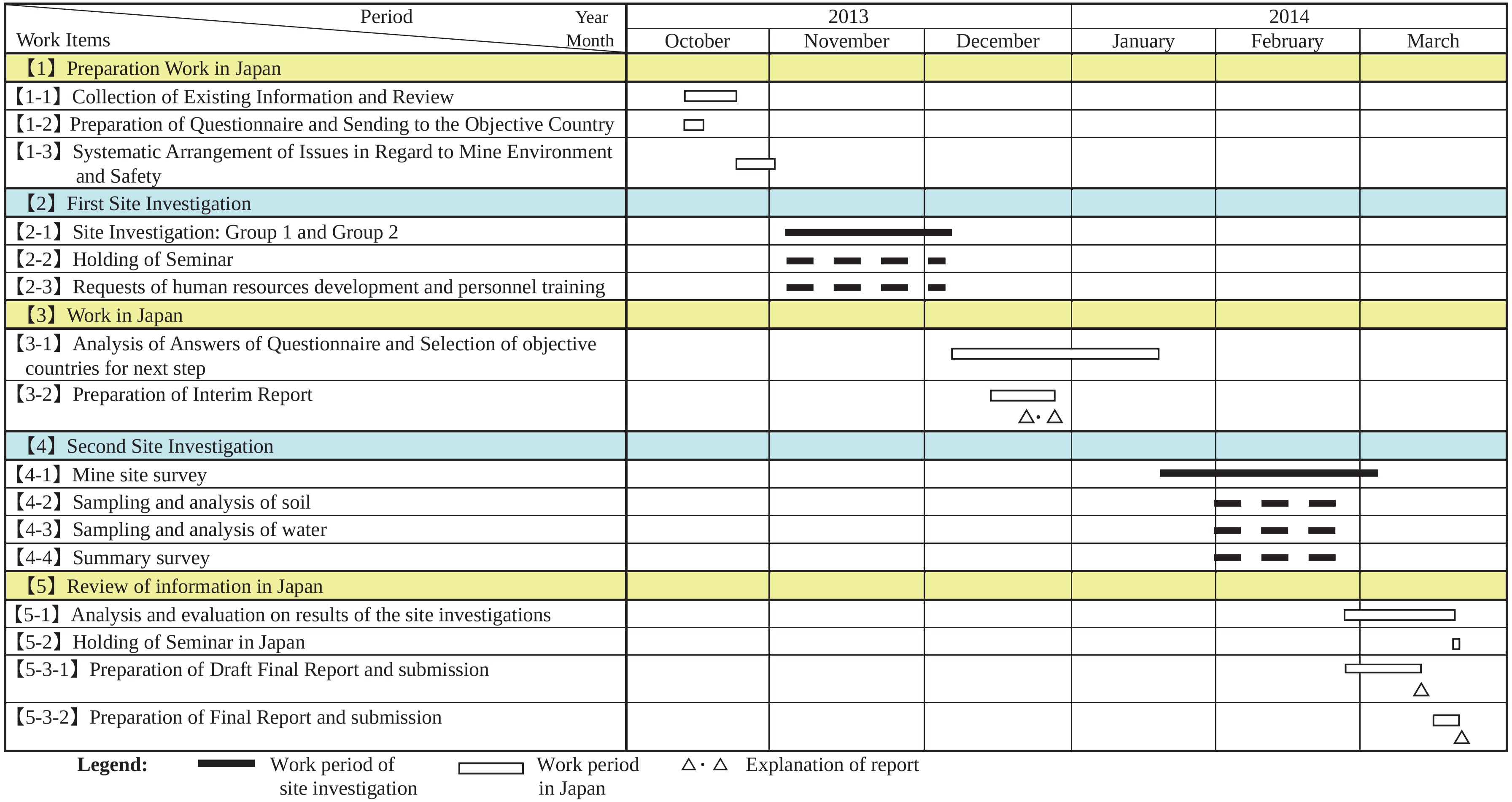


Figure 1.3 Planned Schedule for Working Process

1.7 Organization in charge of the Study

The organization in charge of this investigation and survey work is a joint venture of Mitsubishi Materials Techno Corporation and Sumiko Resources Exploration and Development Co., Ltd., and JICA Study Team. The Study team has four persons under the general management of Mr. Mikio KAJIMA as listed below:

1. Team leader / Mine environment A	Mikio KAJIMA (MMTEC)
2. Mine safety / Mining B	Takayuki YOKOYAMA (MMTEC)
3. Mining A / Mine environment B	Yoshimitsu NEGISHI (MMTEC)
4. Geology /Geochemistry / Remote sensing	Hirohisa KOBAYASHI (SRED)

N.B.: Abbreviations of companies used in the bracket of above are as follows:
MMTEC : Mitsubishi Materials Techno Corporation
SRED: : Sumiko Resources Exploration and Development Co., Ltd.

The First Site Investigation on matters in regard to mine environment will be mainly carried out by Team leader/Mine environment-A with the collaboration of the person in charge of Mine environment-B. As for mining safety, the First Site Investigation will be carried out by Mining-A with the collaboration of the person in charge of Mining-B.

CHAPTER 2   CONTENT OF THE STUDY

The following is a discussion of these three steps in detail.

2.1   Preparation Work in Japan

The Preparation work in Japan consists of collection and review of the existing information and data available, preparation and sending of questionnaire to the objective country and systematic arrangement of issues on mine environment and safety.

2.1.1   Collection and Arrangement of Existing Information and Data

The collection and review of information on the states, etc. of laws regarding mining industry, mining policies, existence of the national mining company and its outlines, if any, the government organization that looks after mining industries, project for mineral exploration, operation of mines and small-scaled mines (SSM) in the objective country, is to be prioritized.

Also, information and data on the superiority of technologies on mine pollution and remediation measures, owned by Japanese enterprises and/or organizations that can be used in the country of study are to be collected and reviewed. This information will be used for discussion for determining the support from JICA.

2.1.2   Preparation and Sending of Questionnaire to Countries to be investigated

Based on the existing information and data collected, questionnaires on mine environment and safety will be prepared in order to obtain present quantitative and qualitative data. The questionnaire is to be sent the objective country through the representative office of JICA. Details of queries are as follows:

(Mine Environment)
Drainage water form mine, piling area, current state of vegetation and those blighted upon mine closure, etc. at the mines being operated or closed which are owned by national companies. Also, the possibility of carrying out analysis in the objective country is to be included in the questionnaire since such analysis is planned to be carried out at the Second Site Investigation.

(Mine Safety)
For mines being operated and closed, the enactment time of the mine safety act, details of the same, and implementation system of the supervisory authority for safety (organization, number of personnel, etc.), and the number of disaster and accident occurred at mines, etc. are to be included in the questionnaire.

2.1.3 Systematic Sorting-out of Issues on Mine Environment and Safety

Issues on mine pollution and disaster are to be sorted out in types, their causes and the method of investigation used. Discussion and summary of this will then be done. Also, presentation documents for the seminar to be held at the First Site Investigation are to be prepared with consultation and discussions with JICA.

The systematic classification of issues on mine environment and safety, and the items to be presented at the seminar are as follows:

- -Considerations and cares to environment and society through the whole life of the mine,
- -Legislative system and supervisory organization relating to mine environment,
- -Explanation on measures to prevent mine pollution in Japan with actual examples,
- -Explanation on conceptual diagram regarding the support for mine environment and safety in Africa, and
- -Explanation on the study work and work flow.

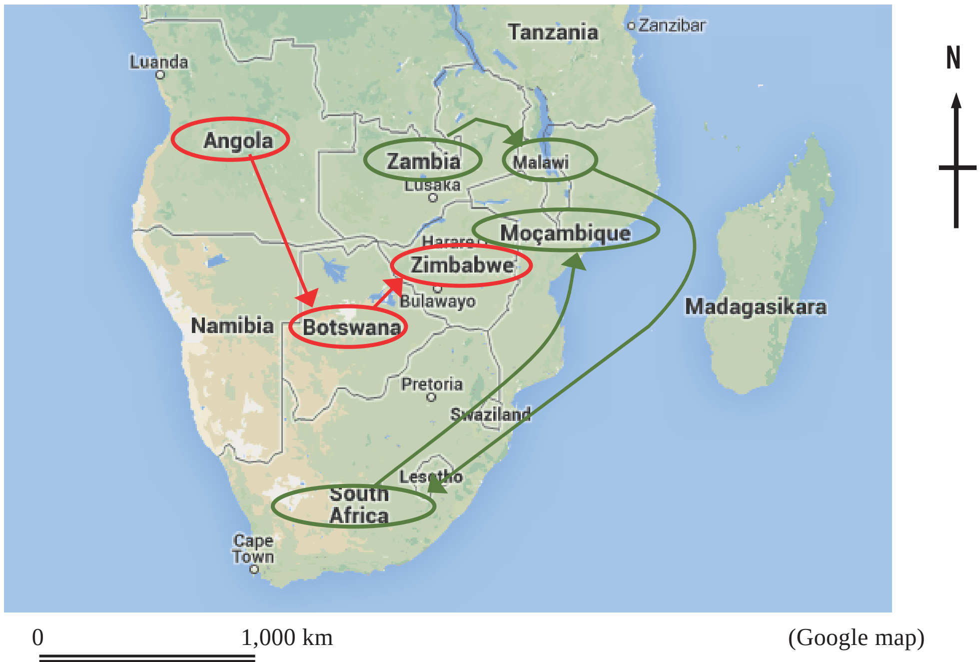
2.2 First Site Investigation

The first Site Investigation work was carried out by two groups. The classification of countries where the site investigation was carried out by respective groups is shown below in Figure 2.1.

1) Scope of Area investigated by Group - 1 : Angola → Botswana → Zimbabwe
2) Scope of Area investigated by Group - 2 : Zambia → Malawi → Mozambique → South Africa

The First Site Investigation work includes collecting and reviewing information and data regarding mine environment and safety of the objective country, holding of seminar, and the collection/confirmation of demands relating to the development of human resources from the organization concerned in the objective countries.

Details on the information on mine environment and safety that has to be collected is given below.



Objective countries by Group-1

Objective countries by Group-2

Figure 2.1 The countries that are investigated by the respective Groups.

2.2.1 Collection and Review of Information relating to Mine Environment and Safety in the Objective Countries

Items to be collected and reviewed in connection with the mine environment and safety are:

(Policy, Legislative and Management Systems on Mine Environment and Safety)

-Policy on mine environment and safety : Policies on mine environment, on suspended or abandoned mines and on mine safety,

-Legislative system on mine environment and safety : Fundamental laws (i.e. Mining Law, Mine Safety Act, regulations and ordinances, etc.), relating laws and regulations (Environmental impact assessment act, pollution control laws of respective kinds, respective environmental standards, management law of mine closure, waste control act, laws relating to water, agriculture, environment, rivers, landslide prevention, etc.), relating guidelines (guidelines, manuals and technical guidelines of various kinds), and

-Management System relating to mine environment and safety : Organization, personnel and budget of government offices relating to management and control (organization chart and management flow), pamphlet, newsletter, report, etc., history of management system, international organization concerned, state and history of international cooperation such as support between two countries, etc.

(Kinds, Numbers and State of Operation of Mines)

-Items to be collected for operating mines : Name and location of mine, name of operating company, kind of minerals, date of permit obtained, scope of development (area), year of operation commencement, period of operation, scheduled year of mine closing, method of mining, mining production (daily and annual production), method of mineral dressing, number of employees, quantity of industrial wastewater, quantity of drainage, quantity of waste disposed, state of waste disposal areas, quantity of tailings, state of piling area for tailings, etc.

-Items to be collected for suspended and abandoned mines : Name and location of mine, name of operating company, kind of minerals, existence of permit obtained, scope of development (area), year of operation commencement, period of operation, year mine closed, method of mining, mining production (daily and annual production), method of mineral dressing, number of employees (at the highest stage of development), state of mine facilities, state of waste disposal areas, state of piling areas for tailings, management system after mine closed (monitoring, etc.), and

-Items to be summed up : Number of operating, suspended and abandoned mines as well as mines scheduled to be developed, state of respective mines (refer to the above items), result of monitoring, plan and carrying out of respective countermeasures, etc.

(Existence, Kinds and State of Issues in Regard to Mine Environment)

-Issues on mine environment : Existence of environmental issues, (items mentioned hereafter are those in case of existing environmental issues) ; kind of issues, location where the issue occurred, result of monitoring, scale of issues (for example, quantity of exhaust gas, quantity of drainage, quantity of contaminated soil , noise level, etc.), state of harm and/or damage (number of sufferer, state of relief measures, state of closing plan for mine, degree of recognition by local inhabitants, disclosure of information, state of investigation/protection measures, etc.,

-Potential occurrence of environmental pollution due to mining : Existence of potential, (items mentioned hereafter are those in case of existing potentials) ; kind of potential, location of such pollution expected to occur, result of monitoring, expected scale of pollution, expected state of harm and/or damage, probability in occurrence of harm and/or damage, etc., and

-State of response on mine environmental issues from national government and/or local government.

(Existence, Kind and State of Issue(s) relating to Mine Safety)

・As to the mine safety, the prevention of harm to people in mine, the protection of mineral resources, and the preservation of mine facilities are to be discussed and evaluated.

・Issues on mine safety : (in respect to items classified by kind of work)

1) Prevention of harm and/or injury to people in mine : Existence of issues on safety, (items mentioned hereafter are those in case of existing issues on safety) ; kind of issues, place

where the issue occurred, causes of occurrence, state of harm and/or injury (number of sufferers, death and the state of harm and/or injury, etc.),

2) Protection of mineral resources : The purpose of this item is to reasonably carry out the mining work of finite mineral resources and to prevent loss of resources due to spontaneous combustion, inundation, etc., and it is realistic to considered that the protection of mineral resources can be obtained by increasing the actual production yield of resources, prior prevention of loss of resources due to the stoppage of mining work from accident, etc. in the mine shaft or pit, etc. As the policy of national government plays an important role to the matters in this item, this is not specifically discussed and described herein., and

3) Maintenance of Mine Facilities : As the mine facilities such as mine gallery, shaft, pit, etc. are essentially difficult to be substituted for, the maintenance work of mine facilities is required to be carried out as first priority. The matters in this item are not discussed herein.

-Occurrence of terrorist attack, riot, criminal act : State of harm and/or damage, storage of explosives and the like, becoming social problems, etc., and

-Response from national and regional government on public security in/around mine.

2.2.2 Holding of Seminar

Seminar was to be held in respective objective countries. Attendees to the seminar were to be staffs of the organization concerned (max. around 20 persons), and to be held for about half days.

Items to be discussed in the seminar are as follows:

- -Methods and procedures of considerations and cares to environmental society through the whole life of mine
- -Legislative system and management organization for mine environment
- -Explanations on transition and actual examples of prevention measures against environmental pollution caused by mining in Japan
- -Explanations on conceptual diagram relating to support for mine environment and safety in Africa
- -Explanations on the proposed investigation work and carrying out work flow
- -Explanations on demand for development of human resources from organizations concerned in the objective country

2.2.3 Confirmation and Demand for Development of Human Resources from Organizations concerned in the Objective Country

Investigations on the capacity development (CD) and the development of human resources (i.e. Long Term Training) are to be carried out by discussions with the relevant organizations. Especially, the investigation is to be carried out on the fact that CD and the development of human resources (long term training) are required in what kind of field.

2.3 Work in Japan

2.3.1 Analysis of Answers from Questionnaire and Selection of the Objective countries for the Second Site Investigation

For mine environment, answers from questionnaire are to be classified according to the type of environmental issues and analysis of the same is to be carried out.

1) State of occurrence of mine environmental issues,
2) Capability and possibility of carrying out analysis in the objective countries, and
3) State of public security in the objective countries and mines concerned.

Considering the above, the selection of countries and mines subject to the Second Site Investigation are to be carried out. And, the objective countries are finally determined upon due consultation with JICA.

As to the mine safety, answers to the questionnaire are to be reviewed by classifying them into the present state, issues, suggestions and proposals to the future for respective countries.

2.3.2 Preparation and Submitting of Interim Report (ITR)

The Interim Report is to be prepared by arranging the results of this investigation systematically and submitting.

2.4 Second Site Investigation

The Second Site Investigation was composed of Site Survey in Malawi and Zambia and Additional Investigation in Zimbabwe, South Africa and Madagascar. The Supplemental Investigation was carried out by two groups, i.e. Group - 1 took charge in Zimbabwe and Group – 2 took charge in South Africa and Madagascar as shown in Figure 2.2.

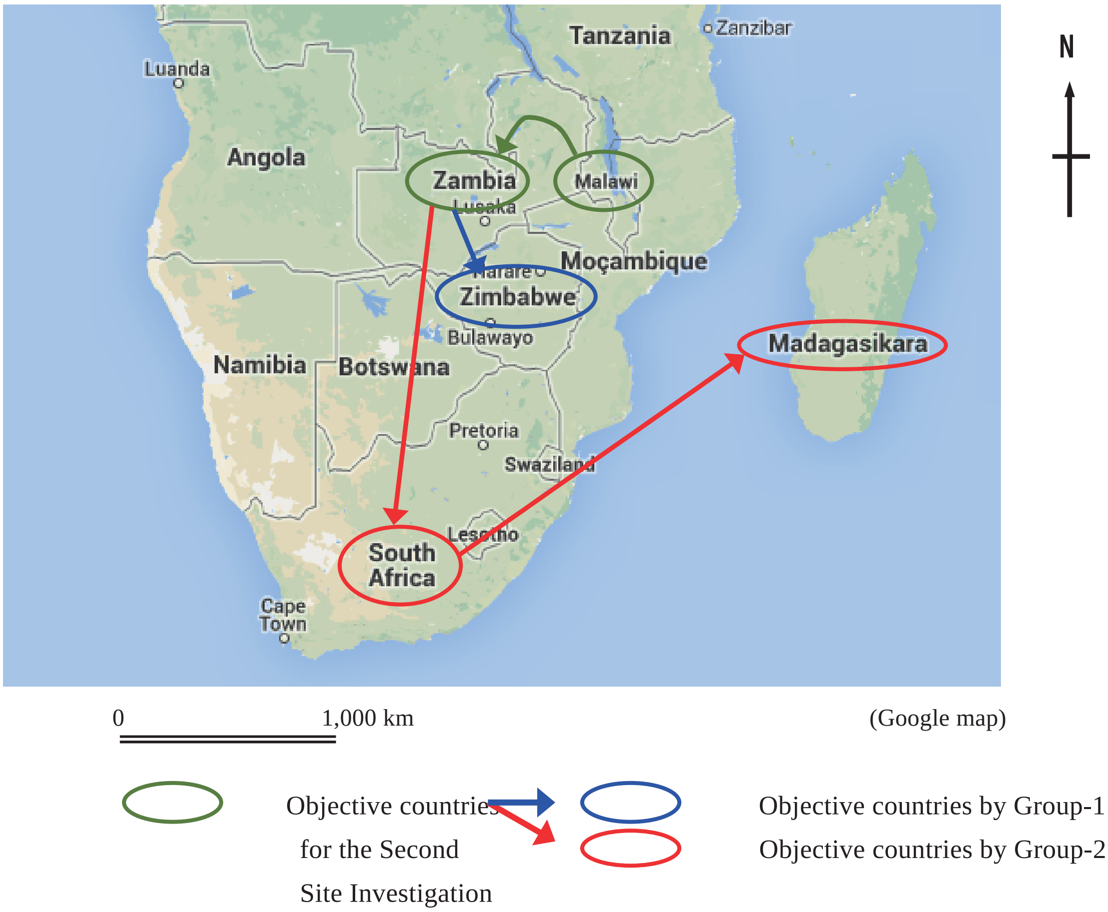


Figure 2.2 Objective Countries and Route for the Second Site Investigation

The content of the Second Investigation consists of site survey, sampling and analysis of soil and water, and summary survey. The content of the Supplemental Investigation is same as that of the First Site Investigation.

The content of each survey are shown as below.

2.4.1 Site Survey

The Site Survey was carried out confirmation of mine pollution (i.e. polluted sites, scale of polluted area, kind of pollutants, concentration of pollutants, etc.) in and around mine sites for understanding schematically on the occurrence of mine pollution, consideration of environmental issues and examination of mine pollution control.

2.4.2 Soil Sampling and Analysis

Soil sampling and analysis is carried out for detailed confirmation of the occurrence of mine pollution. Analytical components are as follows:

- Physical tests: Wet specific gravity, true specific gravity, moisture, grain analysis,
- Chemical analyses: Componential analysis (8 components), elution test analysis (8 components), content analysis (8 components).

Number of samples (20 samples as a mine site in maximum) is decided based on the site condition. The sampling work is done together with staff of relevant organizations.

2.4.3 Water Sampling and Analysis

Water sampling and analysis is carried out for detailed confirmation of the occurrence of mine pollution. Analytical components are as follows:

- Physical items measured in the site: Water temperature, pH, electric conductivity (EC).
- Chemical analyses (9 components),

Number of samples (20 samples as a mine site in maximum) is decided based on the site condition. The sampling work is done together with staff of relevant organizations.

2.4.4 Summary Survey

Summary survey is carried out for examination of measuring area of contaminated zone, drainage system, etc. the number of survey area, number of survey points, etc. is decided based on the answers of questionnaire.

In case that the polluted area is large scale or the boundary of polluted area is not clear, satellite images and DEM data will be used instead of the summary survey.

2.5 Consideration and Compilation Works in Japan

Consideration and compilation works in Japan consist of analyses and evaluation of site investigation results, Seminar held in Japan, formation; submission, explanation and discussion of draft Final Report.

2.5.1 Analysis and Evaluation of Site Investigation Results

The results of the Second Site Investigation and chemical analyses are evaluated and compiled. And then, the supporting policy concerning the mine environment and safety based on the results of the Site Investigations should be recommended to JICA.

2.5.2 Seminar Held in Japan

Seminar on the Site Investigation results is held in Japan in order to inform widely to private sector and relevant domestic organizations. Objective persons for seminar consist of relevant private sector and domestic organizations (100 persons in maximum).

2.5.3 Compilation, Explanation and Submission of the Draft Final Report (D-FR)

Draft Final Report (D-FR) is formed based on the compilation systematically of the Site Investigation results.

2.5.4 Compilation and Submission of the Final Report (FR)

Final Report (FR) is compiled and formed based on the comments of JICA against the D-FR. And, the FR is submitted after the termination of the project works.

CHAPTER 3　First Site Investigation

3.1　Angola

3.1.1　Outline of Angola

(1)　Current State of National Affairs and Economic Indicators in Angola

The current state of national affairs and the economic indicator of Angola are shown in the followings.

- Area : 1,247,000 km^2 (Approximately 3.3 times of Japan, refer to Figure 3.1)
- Population : 20,820,000 persons (in 2012)
- Capital City : Luanda (Population: Approximately 4,500,000 persons in 2009)
- Races : Ovimbundu people (37 %), Kimbundu people (25 %), etc.
- Languages : Portuguese (Official language), Umbundu and others
- Major Industries : (Minerals) Petroleum, diamond
  (Agricultural Products) Corns, feijao, sugar, coffee, sisal hemp, etc.
- GNI (Gross National Income): US$ 115,200 million (in 2012: IMF)
- GNI per person : US$ 5,700 (in 2012: IMF).
- Rate of Economic Growth: 5.2 % (in 2012: IMF).
- Price Increase Rate: 10.3 % (in 2012: IMF).
- Total Amount of Trade: Export: US$ 69,200 million
  Import: US$ 22,800 million (in 2012, estimated by CIA)
- Major Export Goods: Crude oil, diamond, petroleum products, etc.
- Major Trading Partner (in 2012: estimated by CIA):
    - Export : China (45.8 %), USA (13.7 %), India (11 %), South Africa (4.1 %).
    - Import : China (20.8 %), Portugal (19.5 %), USA (7.7 %), South Africa (7.1 %).
- Currency : Kwanza (KZ).
- Exchange Rate : US$ 1 ＝ Approximately 97 Kwanza (in November, 2013)
- General Situation of Economy:

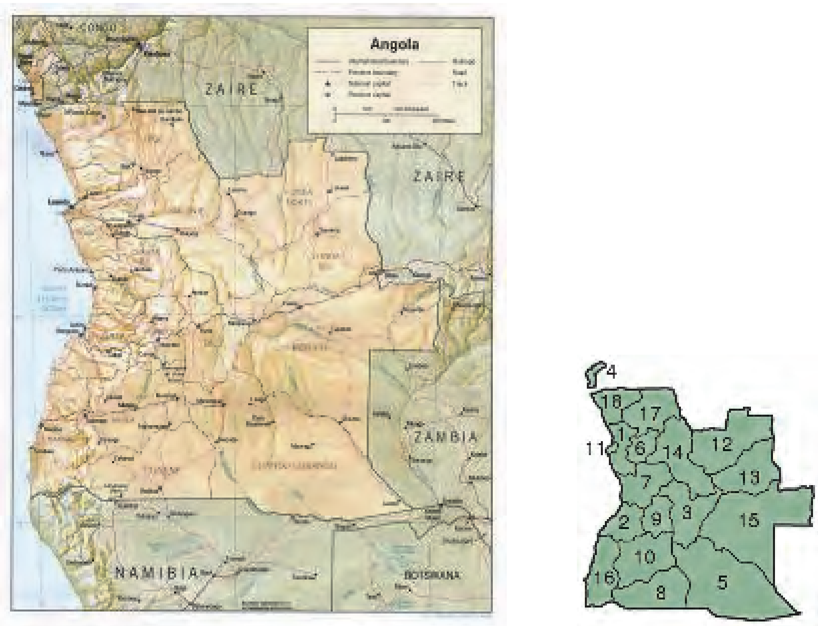
  The economic situation of Angola has extremely impoverished due to the civil war that started after the independence in 1975 and lasted for a long time. However, a high rate of economic growth has been maintained through the country's vast mineral resources such as petroleum, diamond, etc. with the high potential of agriculture and fishing, etc. Angola is the largest petroleum oil producing country in Sub-Sahara Africa region, with equal amount of oil production as Nigeria. Angola became a member of the Organization of Petroleum Exporting Countries (OPEC) in 2007 and acted as the host country in 2009. The government of Angola is planning to carry out the diversification of industries by promoting other industries such as agriculture, forestry, stock breading, hunting and fishing, and manufacturing in order to reduce the economic dependence on petroleum.

- Major Donor Country (in 2009, DAC): USA, Korea, Spain, Norway, Germany, etc.
- Records of International Cooperation and Assistance by Japan:
    (1) Onerous Financial Assistance (~2012, JICA) : None
    (2) Gratuitous Financial Assistance (~2012, JICA) : ¥ 39,383,000,000 (Japanese Yen)
    (3) Technical Cooperation (~2012, JICA) : ¥ 4,789,000,000
- Local Administrative District: 18 states, 158 cities, towns and villages (Refer to Figure 3.1)

(2) State of Nature

a. Geographical Features

The mainland of Angola shares its borders with the Republic of Namibia in the south, with the Republic of Zambia in the east and with the Democratic Republic of the Congo in the north. The west side of country faces the Atlantic Ocean. The province of Cabinda is an exclave being sandwiched between Democratic Republic of the Congo and Republic of Congo.



1. Bengo
2. Benguela
3. Bie
4. Cabinda
5. Cuando Cubango
6. Cuanza Norte
7. Cuanza Sul
8. Cunene
9. Huambo
10. Huila
11. Luanda
12. Luanda Norte
13. Luanda Sul
14. Malanje
15. Moxico
16. Namibe
17. Uige
18. Zaire

Figure 3.1 Map of Angola and its Administrative Division

The coast of Angola has a long and narrow coastal plain 40 to 140 km wide and is still developing with most of the area being dry zone. Northern part of the country and the area of Cabinda are forming tropical rainforests. Most of interior land in the county are high lands having an altitude of 1,000 to 1,600 m, and being utilized for agricultural use. The highest peak in the country is Mt. Moco standing at 2,620 m high and is located approximately at the center of country.

Major rivers in this country are Cuanza River, Cuango River (a branch river of Zaire River), Gunene River, Cubango River, and there is a watershed from northeast to southwest of the country.　Rivers in the northwestern part are flowing down to the Atlantic Ocean, and those in the southeast part are flowing out to Zanbezi River in Botswana and Zambia towards the interior land.

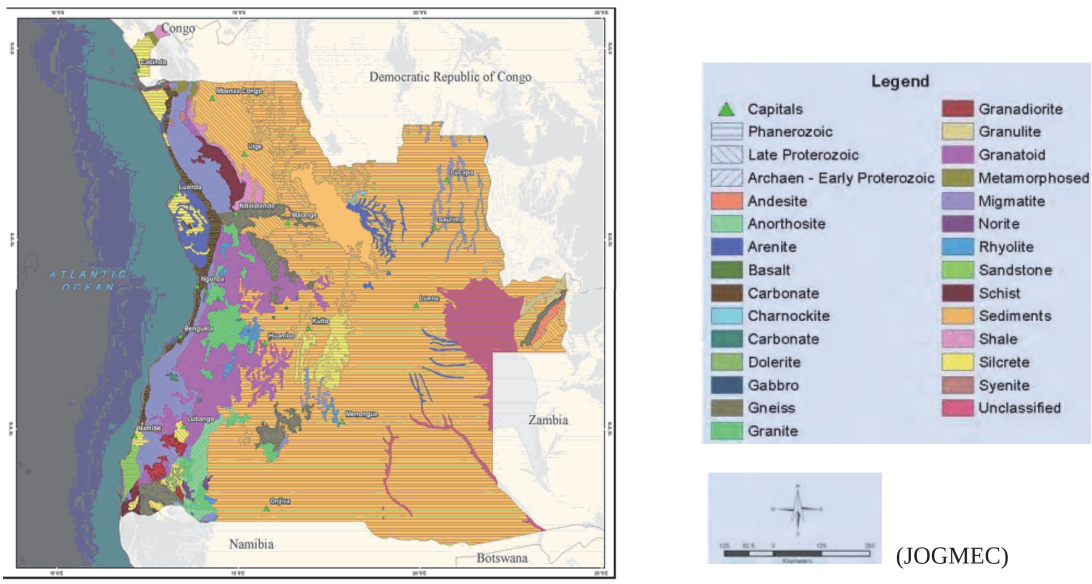
b. Geological Features and Mineral Deposits

The geological features of Angola can be divided into three geological units, i.e. Archean to Early Proterozoic, Late Proterozoic and Phanerozoic (Figure 3.2), different mineral resources are found from the respective geological units.

The geological features of Archean to Early Proterozoic are forming four shields, such as Angolan, etc., as well as Kwanza Horst.　These are mainly composed of granite, greenstone, etc. Huge rock bodies of basic complex with gold ore deposits are distributed at the southwest of Angolan Shield (Figure 3.3).

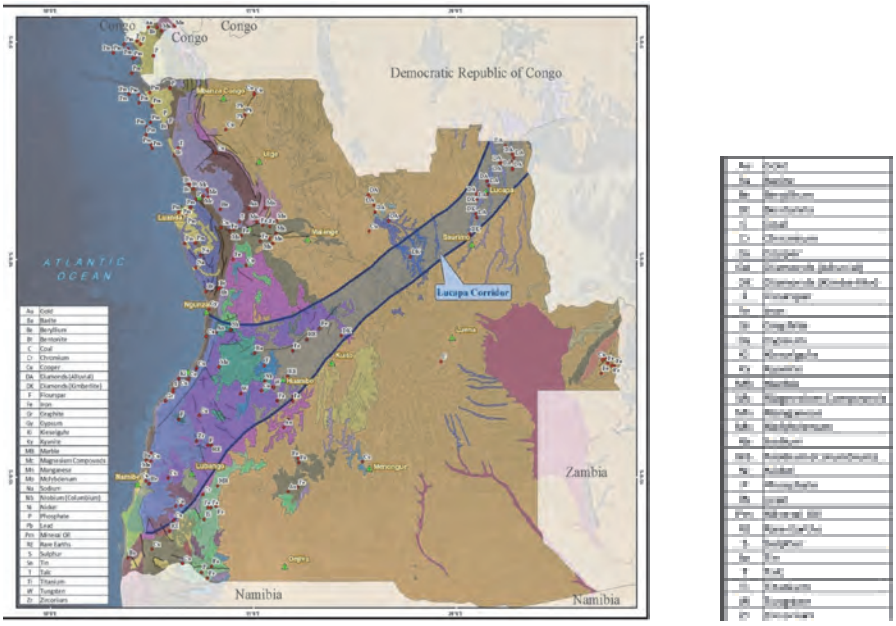
In Late Proterozoic, Pan-African orogenic belt formed, and volcanic rocks including kimberite and carbonatite developed in the rocks.

Phanerozoic is mainly composed of Tertiary to Quaternary, and is distributed and occupies approximately half of eastern parts of Angola.　Marine sediments of Cenozoic are developed in the western part of Angola, and petroleum resources have occurred in these formations.　In addition, industrial minerals such as asphalt, salt, potassium, sulfur, plaster, etc. have also occurred.



(JOGMEC)

Figure 3.2　Geology of Angola



(JOGMEC)

Figure 3.3 Distribution of Ore Deposits and Mineral Showings in Angola

c. Climate

Angola is located in the subtropical zone. The climate is characterized in two seasons, i.e. the rainy season from October to April and the dry season with low atmospheric temperature from May to September due to the influence from Benguela Cold Current, highlands in interior area and Namibe Desert. Precipitation increases in the coastal side and rapidly decreases from 800 to 50 mm towards the south approaching the Namibe Desert.

On the other hand, the interior of the country is classified into three climatic divisions, i.e. the northern area, the central area and the southern area, and the northern area has a climate of high temperature and high humidity, the central area experiences lower temperature (average air temperature; 19 deg. C) and dry, and the southern area is dried.

3.1.2 The First Site Investigation

(1) Time Schedule on Site Investigation

The First Site Investigation in Angola was carried out for five days from November 11 to November 15, 2013.

The time schedule on the first field investigation carried out is as shown in Table 3.1.

Table 3.1 Time Schedule on First Site Investigation in Angola*

No	Month/Day	Time	Place	Item of Work	Persons met
1	Nov./10 (Sun)	-	Haneda–Dubai–Luanda (Angola)	Travelling.	
2	Nov./11 (Mon)	-	Luanda:	Review & Arrangement of Information & Preparation of Investigation.	
3	Nov./12 (Tue)	8:30 - 10:00 - 11:00 - 14:00 -	Luanda: JICA Office MoE MGM Seminar	Courtesy and meeting on Investigation. Courtesy and meeting on Questionnaire, etc. Courtesy and meeting on Questionnaire, etc. At Conference Room of MGM.	Representative and Other Staffs D. of Environment D. of Mines, etc. Attendants: 23 persons
4	Nov./13 (Wed)	9:00 - 10:00 - 12:30 -	Luanda: Geological Institute, MGM MGM MGM	Receipt of Questionnaire and discussions. Meeting on laws, etc. and obtained relating laws, etc. Meeting on environment and safety in mine.	D. of Geology. Legal Dep. D. of Environment.
5	Nov./14 (Thu)	9:00 - 10:30 - 14:00 -	Luanda ˋ: MoE MoE MGM	Receipt of answer & meeting. Meeting on laws, etc. & obtained relating laws, etc. Meeting on environment & safety in mine, development of human resources, etc.	D. of EIA, etc. Legal Dep. D. of Environment
6	Nov./15 (Fri)	8:30 - 10:00 - 14:00 -	Luanda: MGM MGM Japanese Embassy in Luanda JICA Office	Meeting on development of mine & human resources. Meeting on development of mine & human resources. Courtesy and report on outlines of investigation. Report on outlines of investigation	D. of Mines, etc.. Chief, Geological Dept. Officer in charge Representative and Other staffs
7	Nov./16 (Sat)		Luanda – Johannesburg (South Africa)	Travelling	

* Abbreviation in table above mentioned:

MoE :Ministry of Environmental Affairs
MGM :Ministry of Geology and Mines
D. : Director
Dep. : Department
EIA :Environmental Impact Assessment

(2) Governmental Organizations Concerned

The organizations and offices which the delegation visited and the governmental organization, department, division, etc. related to the field investigation are as follows:

Places where the Delegation visited:

- Japanese Embassy in Angola
- JICA Office in Angola

Related Governmental Organization, Directorate, Departments:

- Department of Protection and Environmental Impact Assessment, Directorate of Environment, Ministry of Environmental Affairs
- Directorate of Geology, Ministry of Geology and Mines
- Legal Affairs Department, Directorate of Mine, Ministry of Geology and Mines

(3) Collection of Questionnaire

The questionnaire was prepared during the preparation work in Japan, and distributed to the Directorate of Mine in Ministry of Geology and Mines and the Directorate of Environment in Ministry of Environmental Affairs through the JICA Office in the country concerned prior to the First Site Investigation. These two are the major bodies that are related to the Study.

Initially it was planned that the delegation would collect the answered questionnaires from the respective department when it made the field investigation visit. However, discussions on the answers to the questionnaires were done at the visit and the questionnaires were collected later. This was because the respective departments were not prepared with them at that time. Three sets of answered questionnaires were collected from the Mine Environment and Safety Section, the Directorate of Mines of the Ministry of Geology and Mines, and one set from the Directorate of Environment of the Ministry of Environmental Affairs.

(4) Holding of Seminar

The seminar was held at the conference room for 2.5 hours from 14:00 to 16:30 on November 12, 2013. There were 23 attendees and included people from the Directorate of Mines in the Ministry of Geology and Mines and the Directorate of Geology from the same ministry, persons from the Department of Prevention and Environmental Impact Assessment in the Ministry of Environmental Affairs and the Department of International Cooperation in the same ministry (Table 3.2 and Photos 3.1 and 3.2).

The attendees showed strong in the history of occurrences of environmental pollution caused by mining, the state of harm and/or damage suffered, actual examples of counter measures, considerations and cares on mine environment in Japan and the process of human resources developing by JICA.

(Explanatory Leaflet, etc.)

The seminar was carried out using the projector in the conference room. Presentation materials used in the seminar were two files, namely:

1) Investigation in Africa - Explanation on Background of JICA: Activities of JICA, and
2) Investigation in Africa - Explanation on Mine Environment and Safety, Environmental pollution caused by mining and its countermeasures, etc. in Japan.

Photo 3.1 Seminar Attendees

Photo 3.2 Seminar in Process

(Questions and Answers)

The following queries and discussions were made at questions and answers session in the seminar:

- On the environment of diamond mines,
- On the environment of piling yards for tailings of phosphorous ores,
- On the issues of radioactivity from phosphorous ores, and
- On the scheme of human resources developing by JICA.

Table 3.2 List of Attendants to Seminar

No	Name	Organization / Division*	Position
1	Jelseta Condez	DG of Environment	Directorate General
2	Sandra Nascimento	MoE, DNPAAIA	Director
3	Mihian Jleite Cunha	MoE, DNPAAIA	Staff
4	Vilma Raulo	MoE, DNPAAIA	Staff
5	Jose Muanza	MoE.	Staff
6	Mesquita Vicente Jose	MoE	Staff
7	Santos da Mata	MoE, DNPAAIA	Staff
8	Antonio Jerreira Joaz	MGM, DNM	Staff
9	Ana Paulo Madiths de Souse	MGM, DNM	Staff
10	Osvaldina de Ahulida	MGM, DNM	Staff
11	Albertina Cassule	MoE, Technical of Exchange Office and International Relations (GIRI)	Staff
12	Goreio Simos	DNM	Staff
13	Domingos Goio Guimenecs	MGM, Department of Laboratory, Geologist (IGEO)	Staff
14	Antonio Muaty Chitoponge	GUS de Integcisio	Staff
15	Josefine Cailodasotz Leuis	MGM, Department of Laboratory (IGEO)	Staff
16	Caramb Oalicanto Nancia	MGM, Department of Laboratory (IGEO)	Staff
17	Polcmero Morcalius	MoE	Staff
18	Paulo Nzaji Dinis Sereira	DNM	Staff
19	Jise Peclro Paseoel	MoE, Gebineto Luridico	Staff
20	Jilbrco Picho Nebumbor	MGM, Department of Laboratory (IGEO)	Staff
21	Miguel Paulino A. Almeida	MGM, DNM, director	Staff
22	Domingos Kafanda Jose	MGM, Department of Laboratory, Chief Geologist (IGEO)	Staff
23	Jose Mingra de Rsus	MGM, DNM	Staff
24	Kayo Omachi	JICA, Angola Field Office	Staff
25	Joao Jose Bartolomeu	JICA, Angola Field Office	Staff
26	Takayuki Yokokawa	JICA Study Team	JICA Study Team
27	Mikio Kajima	JICA Study Team	JICA Study Team

* Abbreviation List: The following abbreviations on respective governmental organizations are used in this chapter:

MoE :Ministry of Environmental Affairs
NDPEIA :National Directorate of Prevention and Environmental Impact Assessment
NDM :National Directorate of Mines
MGM :Ministry of Geology and Mines
GIRI :Technical of Exchange Office and International Relations
IGEO :Geological Institute of Angola
D.E. :Directorate of Environment

3.1.3 Policy and State on Mineral Industries

(1) Directorate/Department and Organization in Charge

The organization that is in charge of and carries out all supervisory and administrative work for all mines in Angola is Directorate of Mines in the Ministry of Geology and Mines. This ministry has often been reorganized in the past, and the present organization of this ministry was reorganized by separating the industrial organization from the ministry several years ago. In addition to this, it has been scheduled for the next year, to separate the geological group of department and section from the ministry. The present organization chart of the Directorate of Mines is as shown in Figure 3.4.

The Directorate of Mines is divided into the Department of Management and Control for Mines and Environment, the Department of Management and Control for Mine Technology and Department of Small Scale Mines and Support for Exploration. The chief of the Directorate of Mines and the staff of the Department of Mine and Environment Management who are in charge of mine environment and safety cooperatively support carrying out this Study (Photo 3.3).

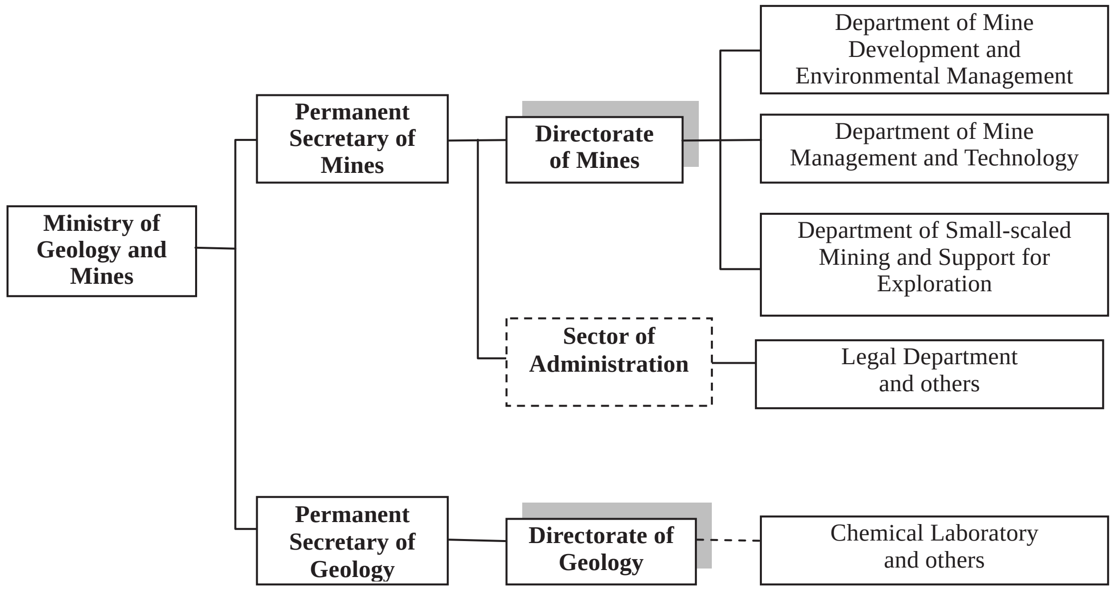


Figure 3.4 Present Organization Chart of the Ministry of Geology and Mines

Photo 3.3 Directorate of Management and Control in relation to Mines

(2) Laws, Acts and Regulations relating to Mining Industries

The Directorate of Mines and the Legal Department in the Ministry of Geology and Mines cooperated and supported the delegation in gathering information on the laws, acts and regulations related to mining industries.

Laws, acts and regulations in regard to mining industries in Angola are presented in Table 3.3.

Table 3.3 Laws, Acts and Regulations in regard to Mineral Industries

No	Laws, Acts, etc. relating to Mines	Legislation No. (Year enacted)	Outlines
1	(Old) Mining Law	No. 1/92 (1992)	・All minerals belongs to the government of country. ・License of Exploration and the right of mining are to be granted, managed and controlled by the Ministry of Geology and Mines. ・The report describing data, etc. while carrying out of business are to be prepared and submitted. ・There is no specific articles for small scale mining. ・Carrying out of EIA, compliance of environmental protection, etc. ・Others.
2	Mineral Law (Act of Diamond)	No. 16/94 (1994)	・Scientific findings on the preparation of geological map, exploration of mineral ore, dressing, sales, etc. are to be applied to the operation and development. ・Laws, etc. on the mining of diamond. ・Others.
3	(New) Mining Law	No. 31/11 (2011)	・As this new law covers wider range than that of old mining law, the old law is to be abolished. ・Strategic mineral ores are petroleum oil, gas, gold, diamond, and radioactive substances. ・Petroleum oil and gas are not included in this law. ・Legislation of small scale mining. ・Compliance to the duty of investigation on EIA, complete carrying out of the obligation on environment, obligation to the report on environment, obligation for the compensation to environmental harm and/or damage, obligation to the payment to Fund for Environmental Conservation (deposit money as security),etc. ・Others.
4	Oil Activity Law	No. 10/04 (2004)	・Laws, etc. relating petroleum business.

The Mining Law of Angola was enacted in 1992 after the end of the civil war. The new legal framework of mining policy is reflected therein for the purpose of excluding the monopolizing of any kind of minerals, increasing investment chances by the private sectors and the proposal for exclusive government managed enterprise. The new Mining Law was enacted in 2011 and the old Mining Law and Diamond Law were abolished. The new law has a wider applicable range than the old one. However, the transition to the new Mining Law might not be very smooth and considerable twists and turns are expected in future.

(Laws, Acts, etc. relating Mine Environment)
The new Mining Law is improved as it requires wider and more considerations and cares to be paid to the environmental society compared to the old law.

The laws, acts, etc. in relation to mine environment that has been enacted, and other laws, acts, etc. that are under discussions for enactment are listed below. Most of them have been approved by the Parliament and the President, and are expected to be enacted next year.

(Laws, etc. already being enacted)

- Fundamental Law of Environment (No. 5/98, in 1998)
- Environmental Impact Assessment Law
- Industrial Waste Management Law
- Safe Water Act
- Water Environmental Quality Standard

(Laws, et. scheduled to be enacted in future)

- Laws relating to Water Pollution
- Laws relating to Soil Contamination
- Laws relating to Noise Prevention, and others

N.B.: As to the standard for drinking water, the Standard of WTO is applied.

(3) Policy for Mining Industries

The economy and its growth in Angola are largely dependent on industrial fields. In 2008 and 2009, 75% of the government's annual income and 96% of exported goods were from industrial fields. The important mineral resources are petroleum and diamond and their production accounts for 85 % of the total mineral production in this country.

Although the mining of cement, crushed stones, rock salts, iron ores, etc. continued, the mining of minerals other than nonmetallic ores such as crushed stones, etc. was suspended due to the civil war.

However, reconsiderations to the development of mineral resources other than petroleum and diamond have been carried out as a recent trend and the movement to increase the investment for exploration of mineral resources can be seen under the new Mining Law, also the development of iron, copper, etc. would soon appear.

(4) State of Mining Industries

In Angola, small scale mining, smelting and refining of gold, copper and iron was done prior to colonization by the Portuguese. However, operations using mechanical equipment began with the mining of diamond (in 1913), copper (in 1930), manganese ore (in 1943) and iron ore (in 1960).

From 1960s to the first half of 1970s, together with diamond and iron ore, gold, copper, tin, beryl, kaolin, etc. were mined. Also, the exploration of iron, non-ferrous ore, uranium, and phosphorous ores, etc. was frequently carried out by enterprises of Portugal, South Africa, Europe and America. However, explorations of deposits in wide area by means of new exploration technologies has not been done in Angola due to guerrilla activities by the people of anti-colonialism since 1961 and the civil war which lasted for a long period.

In 1988, geological maps (6 map sheets) at the scale of 1/1,000,000 were prepared by Soviet team of geology and the structural analysis was carried out using the map of Portugal Age with revisions and additions. However it could not be reached to confirm the potential possibility of the plentiful mineral resources next to South Africa.

Following the above, only a part of alluvial deposits is being operated on in the world-wide-scale group of diamond deposits located at North Luanda Province, northeast of the country. However it is known that resources of niobium, tantalum, rare earth, fluorite, barite, etc. exist.

At present, operating mines of minerals not relating to energy are those of diamond and limestone only. Mines that are operational in the present are listed in Table 3.4 (1) and (2).

Table 3.4 List of Mines, Smelters (1)

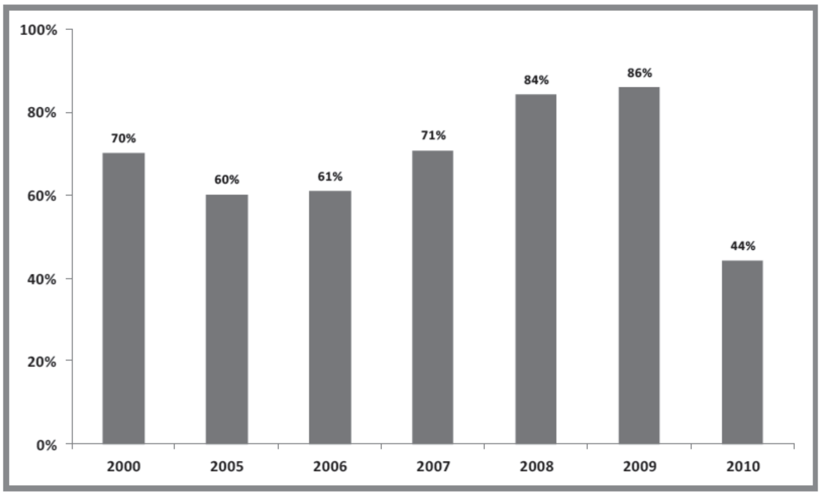
No	Name of Mine	Proprietor（Ratio）	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
1	Secil-Lobito	Companhia de Cimento do Lobito S.A. :TecnoSecil Investimentos Participações SARL (51), G overnment, (49)	Lobito, Benguela Province	Ls	OP	-	0.25 Mt/y	cement		
2	Nova Cimangola	Nova Cimangola S.A. :Government (89), private investors, (11)	Luanda	Ls	OP	-	1.8 Mt/y 0.54 Mt/y	cement clinker		
3	Dundo (ENDIAMA)	Associação em Participação Chitotolo [Empresa Nacional de Diamantes de Angola (45), ITM Mining Ltd.(40), LUMANHE Lda., (15)]	Chitotolo, 95km southeast of Dundo	Dia	OP	-	28 TC/y			
4	Rio Lapi (ENDIAMA)	Empresa Nacional de Diamantes de Angola E.P. (51), New Millenium Resources Ltd.(34), Mombo Lda.(15)	45km northeast of Saurimo, Luanda Province	Dia	OP		240 TC/y			
5	Lunda Norte (ENDIAMA)	Luó-Sociedade Mineira do Camatchia-Camagico	Lunda Norte Province	Dia	OP	-	18 TC/y			
6	Luzamba (ENDIAMA)	Sociedade de Desenvolvimento Mineiro de Angola S.A.R.L (SDM) [Empresa Nacional de Diamantes de Angola E.P. (ENDIAMA),(50), Odebrecht Mining Services Inc., (50)]	Luzamb, Cungo Valley, Luanda Norte	Dia	OP	-	70 TC/y			
7	Catoca (ENDIAMA)	Sociedade Mineira de Catoca Lda. :Empresa Nacionalde Diamantes de Angola E.P. (ENDIAMA) (32.8), ALROSA S.A., (32.8), Daumonty Financing Co. B.V., (18.0), Others (16.4)	Catoca, 36km south of Saurimo, Luanda Sul Province	Dia	OP	-	6500 TC/y			

Table 3.4 List of Mines, Smelters (2)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
8	Cuango (ENDIAMA)	Sociedade Mineira do Cuango [Empresa Nacional de Diamantes de Angola E.P. (ENDIAMA), (41), ITM Mining Ltd. (38), LUMANHE Lda (21)]	Cuango, Cuango Valley, Luanda Norte Province	Dia	OP	-	31 TC/y			
9	Mufuto (ENDIAMA)	Sociedade Mineira do Lucapa Ltd. [Empresa Nacional de Diamantes de Angola E.P. (ENDIA MA), (51), Sociedade Portuguesa de Empreendimentos (49)]	Mufuto Nort	Dia	OP	-	25 TC/y			
10	Calonda (ENDIAMA)	Sociedade Mineira do Lucapa Ltd. [Empresa Nacional de Diamantes de Angola E.P. (ENDIAMA) (51), Sociedada Portuguesa de Empreendimentos, (49)]	Calonda, Lucapa, Lunda Norte Province	Dia	OP	-	27 TC/y			
11	Fucauma (ENDIAMA)	Trans Hex Group Ltd.(32), Empresa Nacional de Diamantes de Angola E.P. (ENDIAMA) (40)	Fucauma, northeastern Angola	Dia	OP	-	120 TC/y			
12	Luarica (ENDIAMA)	Trans Hex Group Ltd.(35), Empresa Nacional de Diamantes de Angola E.P. (ENDIAMA) (40)	Luarica, northeastern Angola	Dia	OP	-	90 TC/y			
13	Somiluana (ENDIAMA)	Trans Hex Group Ltd.(33), Empresa Nacional de Diamantes de Angola E.P. (ENDIAMA) (40)	Somiluana, northeastern Angola	Dia	OP	-	42 TC/y			
14	Gypsum plant	Fábrica de Gesso do Sumbe	City of Sumbe, Cuanza Sul Province	Gypsum	OP		0.2 Mt/y			

* Smelter has not existed in the country so far.

As for mining diamond, Angola produced 13% of all diamonds produced in the world in 2009, by the price converted. The contribution of mining industries to the GDP of Angola is considerably large (Figure 3.5).



(JOGMEC)

Figure 3.5 Contributions of Mining Industries to the GDP of Angola

In addition, as the existence of many metallic deposits and that of various mineral ores as industrial raw materials are being confirmed. The proceedings of the exploration work on these resources are shown in Table 3.4. It is expected that these resources will be developed and worked on in the future.

Ferrangol possesses the mining right for mineral deposits in Cassinga (Huila Province) and in Kassala-Kitungo (Cuanza Norte Province), and it has planned to produce iron ores of 3,000,000 t/year from 2013 in cooperation with ANR of Angola.

Table 3.5 State of Exploration in Angola (JOGMEC)

No	Name of Project	Kind of Elements	Proprietor, etc.
1	Cabinda	P	Minbos Resources Ltd., etc.
2	Mavoio Copper	Cu	AP Services, Genius Minerals
3	Cachoeiras de Binga	Cu, Co	Fortitude Minerals Ltd., etc.
4	Jamba Gold	Au	Huila Province
5	Cassala Quitungo	Fe	Vale
6	Cuvo River	Cu, Co	Unknown
7	Lumbala	Cu, Co	Gevale
8	Kunene	Ni	Gevale

(5) Role of Organization in Charge of Geology and Ore Deposits

The role of the Directorate of Geology (previously, Geological Institute of Angola) is mainly to prepare geological and deposit maps and their management. It is scheduled that Directorate of Geology will be separated from the Ministry of Geology and Mines.

In this Site Investigation, the chief of directorate and his assistants have supported the investigation work.

(Chemical Analysis)
No public organization to carry out the chemical analysis of the quality of atmospheric air, water and soil is established therein.   The required analysis is carried out in South Africa by sending the sample. However on a case by case basis, of respective projects, the environmental analysis is carried out their own way (analyzed by themselves or by subcontractor), and the Ministry receives reports on the result of analysis from them.

At present Directorate of Geology in the Ministry of Geology and Mines have plans to reorganize the Geological Institute as the outside organization of ministry and the new organization will be established and the building for the same will be constructed next year and the chemical analysis center or station will also be constructed.

(6) International Cooperation, etc.

Although it seems that international cooperation in the organization in charge of mines and that in charge of geology and ore deposits has been almost none, there has been technical collaboration such as short term training by the team from France according to the project for preparation of geological maps, the group training for capacity development for the Geological Institute by JICA, etc. have recently been carried out from 2012 to 2013.

3.1.4 Environmental Policy and State of Environment

(1) Organization in Charge of Environment

All management and control relating to environment are performed by the Ministry of Environment.   The number of staffs in the Ministry of Environment is 230 persons at present.

The Ministry of Environmental Affairs looks after matters of management of environmental impact assessment (EIA), plan for environmental management, permit for environment, reports on environment (i.e. monitoring), etc. relating to the mine development.

Photo 3.4 Meeting with the Staffs of the Directorate of Environment

(2) Laws, etc. relating to Environment

a. Laws, Acts, Regulations on Environment

The laws, etc. relating to environment charge to fulfill the obligation of “Compliance with the Obligation according to Investigation on Environmental Impact Assessment”, “Establishment of Measures to protect Natural Environment”, “Promotion of Safety, Health, Sanitation and Public Sanitation”, “Notice in regard to Industrial Accident and Occupational Disease”, “Report on Data relating to Mining Activities including various factors”, “Report on the Influence of Mining Activities to possession of Soil and Characteristics of Environment”, “Required Conditions in connection with Mine Closing”, “Compensation for harm, damage, loss, etc. suffered by the third party and/or person” and “Right of indigenous people” as considerations and cares to environmental society relating to mines.

Laws, acts and regulation in relation to environment are as follows:

(Laws)

- Environment Law (No. 5/98): Including the environmental impact assessment
- Law of National Park (No. 38/11)
- Environment Protection Law (No. 3/06)

(Cabinet Order)

- On Environmental Impact Assessment (Cabinet Order No. 51/04)
- Environmental Permit (Cabinet Order No. 59/07)
- On the Environmental Permit (Cabinet Order No. 96/09)

(Regulation)

- Regulation on Management of Wastes and Residuals
- Regulation on Water Quality: Water environment standard, waste water standard, etc.
- Regulation regarding to Responsibility of Harm and Damage

Also, as to indigenous people, "Law on Right of Indigenous People" is separately enacted and the application of this law is clearly stipulated in this new Mining Law.

b. Procedures of Environmental Impact Assessment (EIA)

The process of EIA in Angola is shown in Figure 3.6.

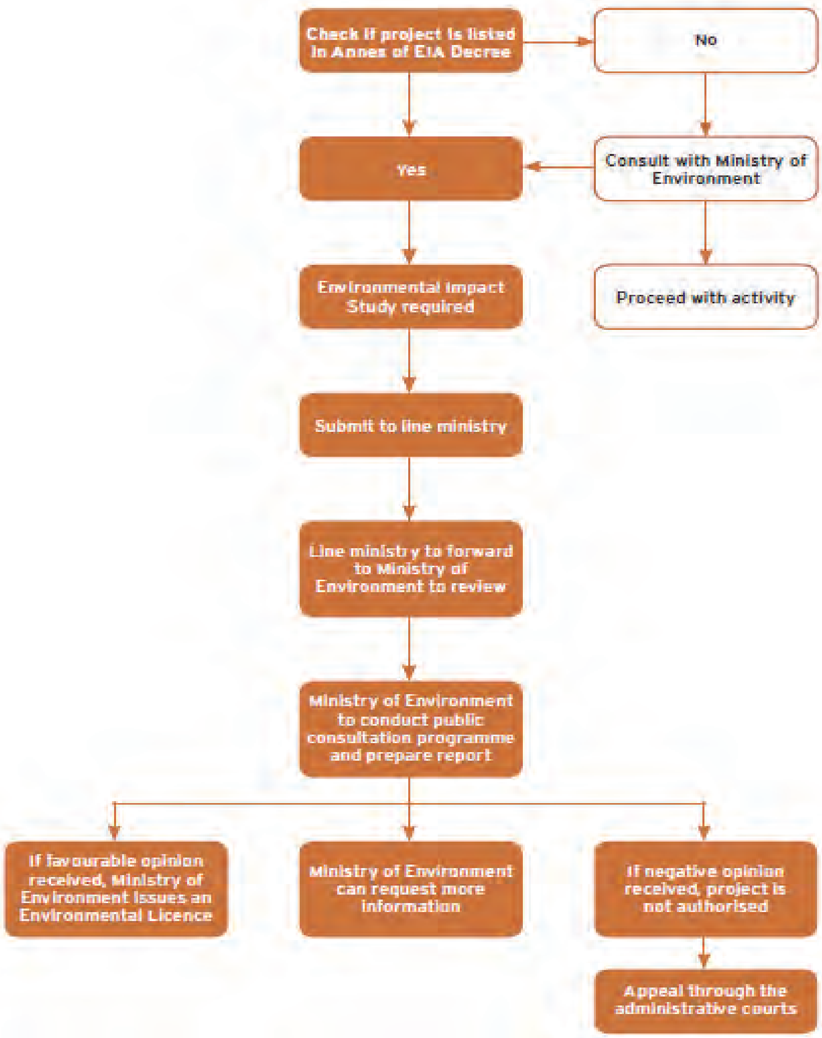


Figure 3.6 Procedures of EIA in Angola

The Ministry of Environmental Affairs is in charge of all EIA in relation to the development of mines and EIA report is to be submitted to the Ministry of Environmental Affairs. The review and examination on technical matters in the report is to be carried out by the section in charge of environment in the Directorate of Mines in the Ministry of Geology and Mines and the result is to be submitted as its comments. Subsequently, the “Permit of environment” is to be granted upon the approval at the general review and examination on overall matters as the procedures.

However, there is no actual record of EIA regarding to the mine development until now.

The (preliminary) review and examination on environment (i.e. EIA) at the exploration stage may be required depending on its scale, and the main procedures of preliminary ones are similar to that of EIA as stated above.

3.1.5 State of Environment and Audit on Environment such as Monitoring, etc.

(1) Response to Environmental Issue relating to Mines

As for the environmental issues in metallic mineral mines other than development of petroleum and natural gas, the harm and/or damage due to mining have not occurred since there is no such mine existing and operating until now. However, it is known that the environmental issues regarding petroleum development have occurred due to leakage, etc. of crude oil and refined oil.

Execution of environmental management associated to the development of mines, such as plan for environmental management, monitoring, etc., is stipulated in the new Mining Law and the Environment Basic Law. Management and control of environmental issues are scheduled to be carried out strictly to avoid environmental pollution. Moreover, the Directorate of Protection and EIA expressed their interest and expectation for training on EIA relating to mine development by JICA.

(2) Monitoring relating to Mines

The monitoring at mine development is carried out by the enterprise or other organization in charge of mine operation and the result of monitoring is assessed by the Directorate of Mines.

3.1.6 Mine Safety

The obligations, i.e. “Promotion of safety, health, sanitation and public sanitation”, “Notice in regard to industrial accident and occupational disease”, “Report on data relating to mining activities including various factors” and “Compensation for harm, Damage, loss, etc. suffered by the third party and/or person”, are clearly stipulated in the new Mining Law previously described.

The information on the present state of mine safety in Angola that has been obtained are:

- Although outlines of mine safety are stipulated in the relating article of the Mining Law, “Mine Safety Law” has already been approved by the parliament and will expectedly be enacted next year or later.

- The specific Safety Regulation corresponding to respective kind of mineral ores has not been enacted, and the enactment of the same will be future issues.
- EIA on the development of mines is to include matters of mine safety as well and this matter is to be in charged by respective mining companies.
- Accidents etc. in connection with the mine safety has not occurred yet since there is no operating mines in this country. However, there is the information on the (small scale) leakage accident, etc. in the development of petroleum oil and/or gas.

Practical measures and plans on the mine safety could not be obtained, however, it is understood that the mine safety is a concerning issue from high concerns on the same shown in the seminar, etc.

3.1.7 Present State of Human Resources Development and Request for Technical Training

(1) Present State of Human Resources Development

It is noted that the development of human resources has not been carried out by the Ministry of Geology and Mines by itself. As for the support for human resources development in this ministry by the donor countries, BRGM had once carried out a short term training (2 to 3 months) for three geological officers in the year of 1990s during the execution of geological map preparation project. Since the year 2000, JICA carried out short term training on mines of three persons (2 to 3 months, including training in Kosaka Training Center of JOGMEC). Also, several persons participated in Remote Sensing Training Center of JOGMEC in Botswana, however other overseas training has not been carried out.

(2) Request on Technical Training in Japan

Demands in relation to the future development of human resources from the Directorate of Mines and Directorate of Geology in the Ministry of Geology and Mines as well as those from the Ministry of Environment are shown below.

- Long term training : 1 to 2 years (including the master course)
- Short term training : 1 to 3 months

(Directorate of Mines, Ministry of Geology and Mines)

As staffs in this Directorate have less experience on the actual works, the training on the actual services of mine management and control will be required.

- GIS : 2 persons (Long term 1*, Short term 1*)
- Calculation method of ore reserves : 3 persons (Long term 1*, Short term 2*)
- Mine planning : 2 persons (Long term 1*, Short term 1*)

- Mining : 3 persons (Long term 2*, Short term 1*)
- Mine safety : 2 persons (Long term 1*, Short term 1*)

(*: person/persons)

(Directorate of Geology, Ministry of Geology and Mines)

This Directorate has plans to establish the analysis center (or station) and plan to construct facilities (already budgeted), however the development of human resources has not been planned yet. Accordingly, it was their strong desire that the support for human resources developing would be carried out.

- Chemical analysis : 2 persons (Long term 1*, Short term 1*)
- Physical exploration : 2 persons (Long term 1*, Short term 1*)
- Geochemical exploration : 2 persons (Long term 1*, Short term 1*)
- Hydrogeology : 2 persons (Long term 1*, Short term 1*)
- Investigation of ore deposits : 2 persons (Long term 1*, Short term 1*)
- Management of analysis station : 2 persons (Long term 1*, Short term 1*)
- Environmental impact assessment : 2 persons (Long term 1*, Short term 1*)

(*: person)

(Ministry of Environmental Affairs)

The ministry desires to receive training on EIA for their staffs since they have few practical works relating to EIA. However, as the middle class staffs are receiving such training, the training for short period of one or two months with the exception of one person.

- Method of EIA : 4 persons (Short term; 3*, Long term; 1*)

(*: person/persons)

3.2 Zambia

3.2.1 Outline of Zambia

(1) Current State of National Affairs and Economic Indicators in Zambia

The current state of national affairs and the economic indicators of Zambia are as follows:

- Area : 753,000 km^2 (Approximately 2 times of Japan, refer to Figure 4.1).
- Population : 20,820,000 people (in 2012).
- Capital City : Lusaka (Population: Approximately 1,700,000 persons in 2011).
- Races : 73 tribes (Tongan, Nyanja people, Babemba and Lund people).
- Languages : English (Official language), Chibemba, Nyanja and Tongan.
- Major Industries : Agricultural Products (Corn, tobacco, peanut, cotton, coffee, etc.), copper mining and copper products, constructions, food products and tourism.
- GNI (Gross National Income): US$ 15,600 million (in 2011: WB).
- GNI per person : US$ 1,160 (in 2011: WB).
- Rate of Economic Growth: 5.9 % (in 2011: WB).
- Price Increase Rate: 8.5 % (in 2010: WB).
- Total Amount of Trade: Export: US$ 9,201 million.
  Import: US$ 6,359 million (in 2011, estimated by CIA).
- Major Export Goods: Copper, cobalt, electricity, tobacco, flowers, cotton, etc.
- Major Trading Partner (in 2011: estimated by CIA):
  - Export : China (34.8 %), Switzerland (18.3 %), South Africa (11.7 %).
  - Import : South Africa (33.4 %), Congo (21.9%), China (10.6 %).
- Currency : Zambia Kwacha (ZMK).
- Exchange Rate : US$ 1 ＝ Approximately 5.5 ZMK (in November, 2013).
- General Situation of Economy:

  Since independence, Zambia has been a monoculture economy depending heavily on copper production which has an export rate of approximately six out of ten. In the current economic situation, copper production and the international copper price has an impact on the Zambian economy. Based on this, the country has given industrial restriction policy the most priority, which is centered on agriculture and tourism.

  Under the World Bank and IMF Executive Board scheme of debt relief for heavily-indebted poor countries, Zambia's was approved on April 2005. After this approval, countries and agencies of each country implemented the debt relief and the external debt decreased markedly.

  Current economy of Zambia is riding high at the moment. This is due to the investment promotion and activities from overseas and increase in copper productions and increase in its price. The rate of economic growth has been approximately 6% so far.
- Major Donor Country (in 2010, DAC): USA, UK, Norway, Japan, Holland, etc.
- Records of International Cooperation and Assistance by Japan:

(1) Onerous Financial Assistance (~2011, JICA) : ¥ 55,008,000,000 (Japanese Yen)
(2) Gratuitous Financial Assistance (~2011, JICA) : ¥ 105,056,660,000
(3) Technical Cooperation (~2011, JICA) : ¥ 53,224,000,000

- Local Administrative District: 9 states (Refer to Figure 4.1)

(2) State of Nature

a. Geographical Features

Republic of Zambia is located inland in the southern part of Africa and the Nation is a republic. Zambia was once known as British Northern Rhodesia.

Zambia is bordered by Angola, Congo, Tanzania, Malawi, Mozambique, Zimbabwe and Namibia (Figure 3.7).

Most land in the country is highland with rivers flowing through. Southern part of the country forms the Zambezi Basin where Zambezi river runs from east to west and flows to Mozambique. Victoria Falls is located on the border of Zambia and Zimbabwe. In addition, rivers of northern part of country correspond to the upstream of Congo River and water from Lake Tanganyika runs into Kalambo River at southeastern part of the lake.

(Google image)

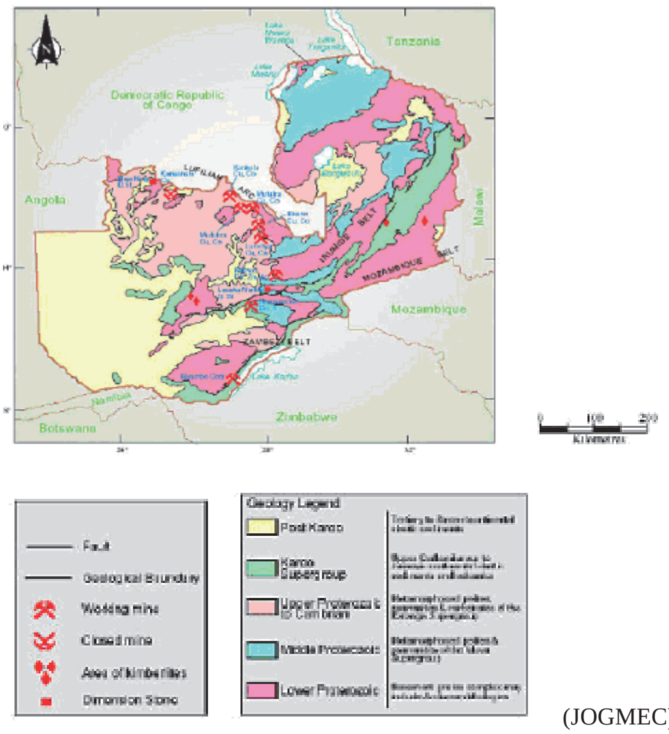
Figure 3.7 Country of Zambia and Administrative Division

b. Geological Features and Mineral Deposits

Geology of Zambia is complex and diverse due to orogeny where the geologies is surrounded by several craters. Earliest rocks as basement are located in the eastern, central and southern part of the country, and consist of granite, granitic gneiss and migmatite. The main structure is uplifted related stratum as the Kafue anticline and domes in the copper belt. Late sedimentary and metamorphic facies cover upper portion of the basements. Thickness of the Bangweulu massif is 5,000m of continental sediments, the apparent thickness suggests that the massif was formed under abnormal situation (Figure 3.8).

Gold, copper, cobalt, lead, zinc, iron, coal and gems are important mineral resources in Zambia. Occurrence of the gold reaches over 300 sites and there are large scale mines such as Dunrobin Mine of Mumbwa District, Dunrobin Mine, Matala Mine and Jessie Mine of Rufunsa District. These gold deposits comprise of mostly vein type where copper and uranium occur as accessory minerals. Copper and cobalt has been mined, over one billion ton as 2.7% Cu ore. In addition, the reserves are still enough to mine 2 billion ores. These copper deposits are precipitated in the sandstone and shale horizons. The deposits also include cobalt which reaches top class production in the world, similar to Congo at the moment.

Kabwe mine located in central part of Zambia has mined lead and zinc ores reaching 11 million ton including 25% Zn and 15% Pb so far. The deposits have precipitated among stratum which consist of Lower and Upper Roan Formation. The deposit types are comprised of massive, brecciated and replacement deposits. Similar mineralizations are recognized at Kabwe in central part and Kapiri Mposhi in northern part of the country (Figure 3.9).



(JOGMEC)

Figure 3.8 Geology of Zambia

(JOGMEC)

Figure 3.9 Distribution of Ore Deposits and Mineral Showings in Zambia

c. Climate

Zambia has a tropical climate and has calm weather in highlands. Annual rainfalls are observed as 500 to 1,500m. The average temperature in Lusaka readings are 21 centigrade in January and 16 deg. C in July. Among these, the dry season is from May to August and rainy season is from December to April.

3.2.2 The First Site Investigation

(1) Time Schedule on Site Investigation

The First Site Investigation in Zambia was carried out for five days from November 11 to November 15, 2013.

The time schedule on the first field investigation carried out is as shown in Table 3.6.

Table 3.6 Time Schedule on First Site Investigation in Zambia

No	Month/ Day	Time	Place	Item of Work	Persons met
1	Nov./10 (Sun)	-	Haneda - Dubai (UAE) - Lusaka (Zambia)	Travelling.	
2	Nov./11 (Mon)	-	Lusaka: JICA Office Ministry of Mines, Energy and Water Development	 Courtesy and meeting on investigation. Courtesy and meeting on investigation.	 Representative and other related staffs Permanent Secretary and Directors of the Ministry
3	Nov./12 (Tue)	 8:30 - 14:30 -	Lusaka: At conference room of Ministry of Mines, Energy and Water Development	 Preparation for Seminar and arrangement of information by investigation. Seminar.	 Mines Development Department, Geological Survey Department, Geological Survey Department and ZEMA Attendants: 9 persons from Zambia
4	Nov./13 (Wed)	 8:30 - 11:00 - 14:00 - 16:00	Lusaka: Geological Survey Department EIA Unit of ZEMA. Mines Development Department EIA Unit of ZEMA	 Discussion, interview, obtained organization. Discussion and receipt of questionnaire. Discussion and receipt of questionnaire. Meeting.	 Director of Geological Survey Department, etc. Principal Inspector, etc. Mining Engineers Principal Inspector
5	Nov./14 (Thu)	 6:30 - 11:00 - 14:00 - 18:00 -	Ndra and Kitwe: Lusaka-->Ndra ZEMA Ndra Office Mufurila Mine, etc. Mines Safety Department	 Travelling. Discussion, receipt of questionnaire and obtained regulations. Had a look around copper mines facilities. Meeting and interview.	 Director and Senior Inspector Senior Inspector
6	Nov./15 (Fri)	 7:30 - 11:00 - 14:00 - 15:00 - 16:00 -	Kabwe: Kitwe-->Kabwe Kabwe Pb-Zn Mine Mines Development Department EIA Unit of ZEMA. JICA Office	 Travelling. Had a look around Pb-Zn mine facilities. Interview and protocol for access for information. Interview and obtained organization chart. Report on outlines of investigation.	 Mining Engineers Inspector Representative and other Staffs
7	Nov./16 (Sat)		Lusaka (Zambia) - Johannesburg (South Africa)	Travelling.	

(2) Governmental Organizations Concerned

The organizations and offices which the delegation visited and the governmental organization, department, division, etc. relating to the field investigation are as follows:

Place where the Delegation visited:
- Embassy of Japan in Zambia
- JICA Zambia Office

Relating Governmental Organization, Directorate, Department, etc.:
- Ministry of Mines, Energy and Water Development: Mines Development Department
- Ministry of Mines, Energy and Water Development: Mines Safety Department
- Ministry of Mines, Energy and Water Development: Geological Survey Department

- Ministry of Lands, Natural Resources and Environmental Protection: Inspectorate Department, Zambia Environmental Management Agency
- Ministry of Lands, Natural Resources and Environmental Protection: Ndra Office, Zambia Environmental Management Agency

(3) Holding of Seminar

Seminar at Zambia was heldint a meeting room in JICA Zambia Office on 12 November. There were nine participants in the Seminar, which included three mining engineers from Mines Development Department, Ministry of Mines, Energy and Water Development, five geologists from Geological Survey Department and one engineer from ZEMA (Photo 3.5 and 3.6, Table 3.7).

To begin the seminar, Mr.Teranishi, representative of JICA Zambia Office, greeted the participants and spoke about the back ground of the study and assistance provided for sustainable mining to the mining sector of Zambia from JICA. After the speech, the study team made their presentation of three files. The presentations attracted the interest of participants.

Photo 3.5 Seminar at JICA Zambia Office
(JICA representative greeting the participants.)

Photo 3.6 Seminar at JICA Zambia Office
(The nine participants.)

(Explanatory Leaflet, etc.)

The seminar was carried out by using the projector of the conference room. Presentation materials used in the seminar were three files, listed below:

1) Investigation in Africa - Explanation on Background of JICA: Activities of JICA, and
2) Investigation in Africa - Explanation on Mine Environment and Safety, Environmental pollution caused by mining and its countermeasures, etc. in Japan, and
3) Investigation in Africa - Explanation on Japanese Experiences for Sustainable Mining in respect to Mine Environment and Safety.

(Questions and Answers)

The issues brought up during the questions and answers during the consultation are as follows:

- Method of management for abandoned mines in Japan
- Rule between government and private sector with respect to the management and counter measure for abandoned mines in Japan
- Supply provider in respect to the management and counter measure for abandoned mines in Japan
- Detail of long-term training in Japan

Table 3.7 List of Attendees to Seminar

No	Name	Organization / Division	Position
1	Mulenga Brian	Mines Development Department, Ministry of Mines, Energy and Water Development	Mining Engineer
2	Mulongwe Simukali	Mines Development Department, Ministry of Mines, Energy and Water Development	Mining Engineer
3	George Milongo	Mines Development Department, Ministry of Mines, Energy and Water Development	Mining Engineer
4	Chishimba Canisius	Geological Survey Department, Ministry of Mines, Energy and Water Development	Geologist
5	Rodwell Chandipo	Zambia Environmental Management Agency, Ministry of Lands, Natural Resources and Environmental Protection	Environmental Inspector
6	Beujy Mateyo	Geological Survey Department, Ministry of Mines, Energy and Water Development	Chemist
7	Ezekiah Chikambwe	Geological Survey Department, Ministry of Mines, Energy and Water Development	Senior Geologist
8	Eyarioto Kasumbia	Geological Survey Department, Ministry of Mines, Energy and Water Development	Geologist
9	Daniel Mutamisa	Geological Survey Department, Ministry of Mines, Energy and Water Development	Geophysicist
10	Yoshihide Teranishi	JICA Zambia Office	Resident Representative
11	Taigo Sasaki	JICA Zambia Office	Assistant Resident Representative
12	Helen Masiye	JICA Zambia Office	Program Officer
13	Hirohisa Kobayashi	JICA Study Team	JICA Study Team
14	Yoshimitsu Negishi	JICA Study Team	JICA Study Team

3.2.3 Policy and State on Mineral Industries

(1) Directorate/Department and Organization in Charge

Mines Development Department of the Ministry of Mines, Energy and Water Development has been conducting audit and management for mining properties and activities including approval and license (Figure 3.10 and Photo 4.3). An approval and a license is required for EIA permission from ZEMA. Inspectors of the department have been enforcing audit and monitoring of the mining operation every three months regardless if the mine has operated adequately or not. Department is not in charge of the permit approval for EIA. The office of the department is located in the government complex same as the ministry in Lusaka (Photo 3.7 and 3.8).

Mines Safety Department of the Ministry of Mines, Energy and Water Development has been conducting audit and management for mining operation and mine safety of the active mines (Photo 4.4). Inspectors of the department have been enforcing audit and monitoring of the mine environment and safety in respect to the mining. The audit and monitoring are enforcedand are a collaborative work with ZEMA. The main office of the department is located in Kitwe. Department is not in charge of the permit approval for EIA as well.

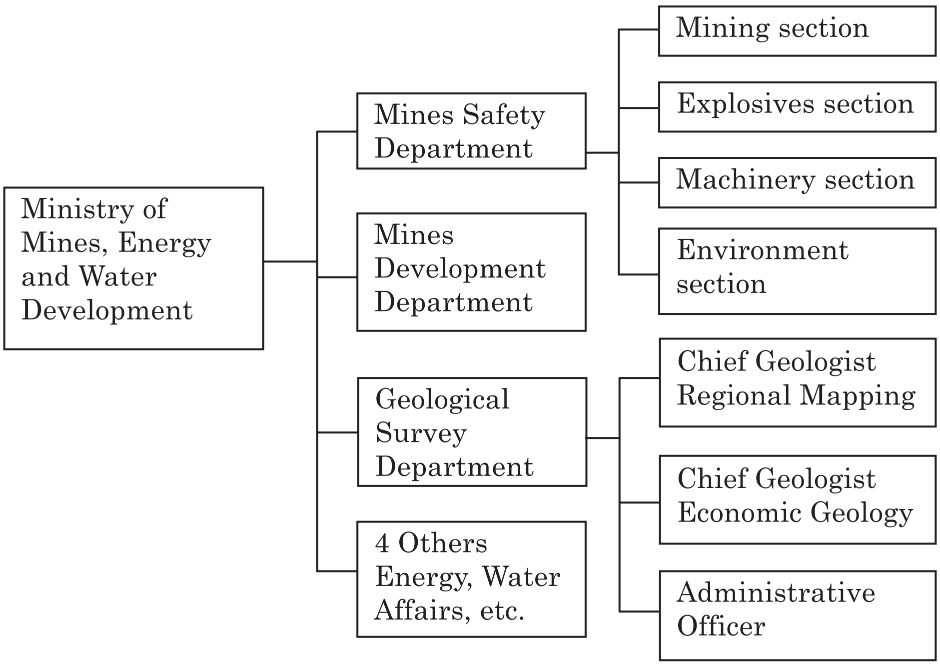


Figure 3.10 Present Organization Chart of
the Ministry of Mines, Energy and Water Development

Photo 3.7 Courtesy call to Ministry of Mines, Energy and Water Development (Interview with the permanent Secretary)

Photo 3.8 Interview with ZEMA Ndra Office (The Office exercises jurisdiction over the Mine Environment of the Copper belt)

(2) Laws, Acts and Regulations relating to Mining Industries

The law relating to Mining in Zambia is the Mines and Minerals Development Act (established in 2008). This law corresponds to the revised version of the Mining Law which was established in 1970. Related law for the mine safety was established in 1973 as a mine regulation and the law is also involved in the Mines and Minerals Development Act in the current situation. These laws are still being revised.

The Mines and Minerals Development Act is composed of the Mining Regulations (established in 1995), the Mines and Minerals (for the environment) Regulations (established in 1997), the Mining (for the environment conservation foundation) Regulation (established in 1998), the Mining and Mineral Development (for the preliminary exploration and mining of uranium and related radioactive minerals) Regulations (established in 2008).

Related law for mine environment is the Environment Management Act (established in 2011). The law corresponds to the revised version of the Environmental Protection and Prevention of Pollution Act (established in 1990) and the government is currently revising the law. The revision of the Environment Management Act is due to be finalized by 2014.

The Environment Management Act is composed of the Hazardous Waste Management Regulations (established in 2001), the Environmental Impact Assessment Regulations (established in 1997), the Air Pollution Control Regulations (established in 1997), the Water Pollution Control Regulations (established in 1993). Drinking water in the country is of WHO standards.

(3) Policy for Mining Industries

Important matters pertaining to the governmental policy are the revision of laws, creation of added value, upgrading of infrastructures (road, railway water and energy), and enhancement of security and conservation of environment. For example, the concrete plan regarding infrastructure and natural environment, there are planned activities for the capacity of electrical power to be upgraded to approximately 2,700MW and an environmental conservation foundation will be established for the enhancement of auditing and monitoring for the natural environment.

The revised raised royalty rate from 3% to 6% in 2011 and stated areas of exploration and exploitation be divided into two categories as large (250km^2 in maximum limit) and small (10km^2 in maximum limit) in 2008.

(4) State of Mining Industries

Mines are concentrated in the Kitwe area of Copper Belt, where smelters and other facilities exist. In addition to these, there are several kind of mines such as Pb-Zn in Kabwe, Ni mine in Kafue, Mn mines in Mansa, and so on (Table 3.8).

40t dump trucks loaded with copper concentrate and other materials pass frequently through Kitwe and Ndra which are the main cities in the Copper Belt.

The number of exploration licenses sits at 71 for large-scale, 391 for small-scale and 132 for jewelries. Current situation for exploration in Zambia is shown on Table 3.9.

Table 3.8 List of Operating Mines (1)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
1	Lumuwana	Barrick Gold Corp (100) [Canada]	Solwezi	Cu, Co, U, Au	OP	2005 -	20 Mt/y	ore	-	-
2	Kansanshi	First Quantum Minerals Ltd (80) [Canada] ZCCM(20)	Solwezi	Cu, Au	OP	2005 -	12 Mt/y 8.4 Mt/y 6.1 Mt/y	sulfide ore mixed ore oxide ore	-	-
3	Nchanga underground	Vedanta Resources plc (79.4) [India] ZCCM(20.6)	Chingala	Cu, Co	UG	? -	2.8 Mt/y	ore	Seep from old tank into the Kafue River	-
4	Konkola	Vedanta Resources plc (79.4)[India] ZCCM(20.6)	Chingola	Cu, Co	?	? -	NA	reprocessing of tailings	Sulphur dioxide pollution	-
5	Fitwaola open pit	Vedanta Resources plc (79.4)[India] ZCCM(20.6)	Chingola	Cu, Co	OP	? -	NA	?	-	-
6	Nkana	Glencore International AG (73.1)[Swiss] FirstQuantum Minerals Ltd(16.9)[Canada] ZCCM(10)	Kitwe	Cu, Co	UG/OP	1932 -	5.5 Mt/y	ore	-	-
7	Mufulira	Glencore International AG (73.1)[Swiss] First Quantum Minerals Ltd (16.9) [Canada] ZCCM(10)	Mufulira	Cu, Co	?	? -	2.5 Mt/y	ore	-	-
8	Mopani	Glencore International AG (73.1)[Swiss] First Quantum Minerals Ltd (16.9) [Canada] ZCCM(10)	Mufuliva	Cu, Co	UG	1990 -	1.87 Mt/y	?	-	-
9	Baluba underground	ZCCM Luanshya Division	Luanshya	Cu, Co	UG	? - 2009	1.8 Mt/y	ore	-	-
	Baluba	CNMC Luanshya Copper Mines PLC[China]	Luanshya		?	2009 -	NA	?	-	-
10	Chambishi	China Nonferrous Metals Group (85)[China] ZCCM (15)	Kalulushi, Kitwe	Cu, Co	UG	2003 -	0.9 Mt/y 0.05 Mt/y	ore Cu conc.	Sulphur Dioxide emitting	-
11	Munali	Jinchuan Group Ltd(18.4) その他(81.6)	Lusaka	Ni, Co, Cu	UG	? -	1.2 Mt/y 1700 t/y 500 t/y	ore Cu conc. Co conc.	-	-

Table 3.8 List of Operating Mines (2)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
12	Mkubwe	?	Ndola	Cu	OP	1998 -	0.7 Mt/y	?	-	
13	Munali	Albidon Ltd[Australia]	60km south of Lusaka	Ni,Cu, Co,Pt	?	2006 -	10.5 Mt/y	ore	-	-
14	Nampundwe	Vedanta Resources plc (79.4) ZCCM(20.6)	48kmwest of Lusaka	Pyrite	?	? -	0.30 Mt/y	ore	-	-
15	Chilanga II plant	Lafarge Cement Zambia	15km south of Lusaka	Ls	?	? -	0.83 Mt/y	cement	-	-
16	Ndola plant	Zambezi Portland Cement LTD Lafarge Cement Zambia	Ndola	Ls	?	? -	0.45 Mt/y	cement	-	-
17	Chilanga I plant	Lafarge Cement Zambia	18km south of Lusaka	Ls	?	? -	0.20 Mt/y	cement	-	-
18	Maamba	Maamba Collieries LTD	350km south of Lusaka	Coal	?	1971 - 2007	0.36 Mt/y	bituminous	-	-
19	Kandabwe	?	Sinazongwe	Coal	?	? -	0.24 Mt/y	bituminous	-	-

Table 3.9 State of Exploration in Zambia (JOGMEC)

Stage	No	Name of Project	Kind of Elements	Proprietor, etc.
Develop-ment	1	Hebei Jidong	Cu,Au	Hebei Jidong Construction Co Ltd (-)
	2	Kabwe	Zn,Pb,V,Cu,Ag,Mn	Alberg Mining and Exploration plc (100)
	3	Konkola Deep	Cu,Co	Vedanta Resources plc (79.4), Zambia Consolidated Copper Mines Ltd (20.6)
	4	Konkola North	Cu,Co	Teal Exploration and Mining Inc (80), Zambia Consolidated Copper Mines Ltd (20)
	5	Muliashi North	Cu,Co	China Non-ferrous Metal International Mining (85), ザンビア政府 (15)
	6	Ichimpe	Cu,Co	Zhonghui Mining
	7	Mushiba	Cu	China Non-Ferrous Metal International Mining (85), ザンビア政府 (15)
F/S	8	Chirundu	U	African Energy Resources (Guernsey) Ltd (100)
	9	Kabwe Tailings	Pb,Zn,V,Cu,Mn,Ag	Berkeley Mineral Resources plc (100)
	10	Mkushi	Cu	Ratel Group Ltd (51), African Eagle Resources plc (49)
	11	Mutanga	U	Denison Mines Corp (100)
	12	Mwambashi	Cu,Co	Teal Exploration and Mining Inc (100)
Drilling	13	Cheowa-Neningombe	Cu,Au,Ag	Zambezi Resources Ltd (49), Glencore International AG (51)
	14	Chingola Dumps	Cu	Zambezi Resources Ltd (100)
	15	Chongwe	Cu,Au	Zambezi Resources Ltd (49), Glencore International AG (51)
	16	Eagle Eye	Cu,Au	African Eagle Resources plc (100)
	17	Fishtie	Cu	First Quantum Minerals Ltd (-)
	18	Kadola West	Cu,Co,Au	Caledonia Mining Corp (-)
	19	Kangaluwi	Cu,Au	Zambezi Resources Ltd (100)
	20	Luanshya	Cu,Co	Unnamed owner (100)
	21	Luiri Hill	Au,Cu	Luiri Gold Ltd (100)
	22	Lumwana Uranium	U,Cu	Barrick Gold Corp (100)
	23	Mokambo	Cu	North Western Plant Hire Ltd (100)
	24	Mokambo South	Cu	African Eagle Resources plc (100)
	25	Mufulira Tailings	Cu	China Nonferrous Metals Group, Zambia Consolidated Copper Mines Ltd
	26	Mufumbwe	Cu	Earthstone Group, M/S Aupie Agro Foam Ltd
	27	Mumbwa	Cu,Au,Ag,U	Blackthorn Resources Ltd (100)
	28	Nama	Co,Cu,Au,Ni	Caledonia Mining Corp (100)
	29	Ndola	Cu	African Eagle Resources plc (100)
	30	Rephidim	Cu	Rephidim Enterprises Ltd (100)
	31	Sebembere	Cu	Local Interest (100)
	32	Trident	Cu,Co,Ni,U	First Quantum Minerals Ltd (100)
Geo-physical	33	Iron Cap	Au	Challenger Development Corp (70), Local Interest (30)
	34	Kawako	Ni	First Quantum Minerals Ltd (100)
	35	Kawanga	U	First Quantum Minerals Ltd (100)
	36	Nyimba	Zn,Cu,Ag	Mukuba Resources Ltd (85), Lukusashi Mining Ltd (15)
	37	Zambezi	Cu	Equinox Minerals Ltd (100)
	38	Zambian Copperbelt	Cu,Co	Korea Zinc Co Ltd (30), African Rainbow Minerals Ltd (70)
Pre-liminary	39	Mpande	U	Zambezi Resources Ltd (100)
	40	Mulofwe Dome	U	Zambezi Resources Ltd (100)
	41	Mwinilunga	Cu,Co	First Quantum Minerals Ltd (-), BHP Billiton Group (-)
	42	Nambala	Fe	Luiri Gold Ltd (100)

(5) Role of Organization in Charge of Geology and Ore Deposits

Geological Survey Department comes under the Ministry of Mines, Energy and Water Development which also encompasses Mines Development Department and Mines Safety Department. The main task of the department is to conduct geological mapping in the country and the geologists are performing the mapping to complete sectional geological maps of the country.

The department is not in charge of mine environment so far. However, the department is planning to carry out the mine environmental work to be conducted by the hydrologist currently employed by them.

(6) International Cooperation, etc.

There is no international support from overseas agencies or enterprises to the above departments in respect to mine environment and safety. On the other hand, the Geological Survey Department has received significant overseas help. JICA supported the department in capacity building during 2007 to 2010, whereby mapping work in the Kasama district and geological GIS configuration work were performed. Short-term experts in this field were dispatched between 2010 and 2011.

As an ongoing support project, 1:100,000 scale geological mapping in the Kasama district has commenced from in 2013 as a bilateral aid between China and Zambia. The project will be completed by 2015.

A total of 26 geologists (2 geologists in 2013) have participated in the remote sensing training program in Botswana Remote Sensing Center.

3.2.4 Environmental Policy and State of Environment

Zambia Environmental Management Agency, Ministry of Lands, Natural Resources and Environmental Protection has been conducting permit approval works for the EIA and audit works as the agencies charged with EIA monitoring of operating mines. Northern Office of the ZEMA at Ndra in Copper Belt acts as a hub for the mine environment works. The office has been auditing and monitoring mines and mining facilities such as smelters and so on in the Copper Belt. The audit and monitoring works are enforced collaborative works together with Mines Safety Department of the Ministry of Mines, Energy and Water Development.

(1) Organization in Charge of Environment

Organization of environment related departments are as follows:

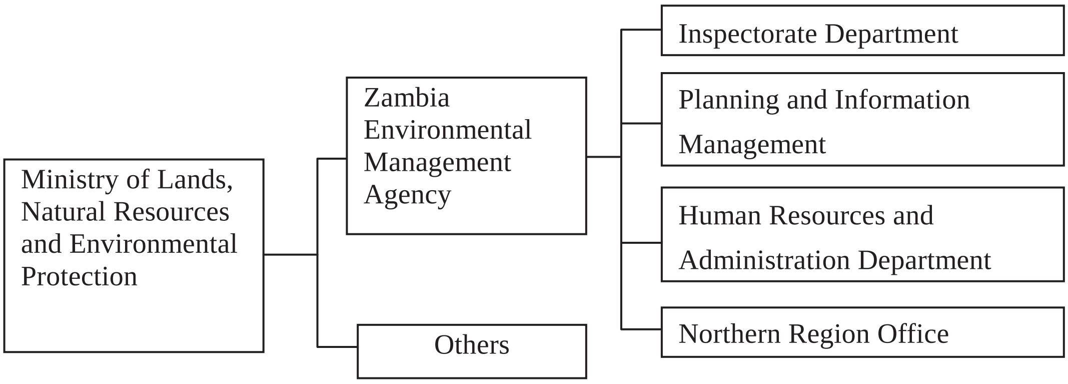


Figure 3.11 Present Organization Chart of the Ministry of Lands, Natural Resources and Environmental Protection

(2) Laws, etc. relating to Environment

Related law for the mine environment is the Environment Management Act (established in 2011). The law is builds upon the revised version of the Environmental Protection and Prevention of Pollution Act (established in 1990) and the government is still revising the law at the moment. The revised upgrading for the Environment Management Act is due to be finalized by 2014.

The Environment Management Act is composed of the Hazardous Waste Management Regulations (established in 2001), the Environmental Impact Assessment Regulations (established in 1997), the Air Pollution Control Regulations (established in 1997), the Water Pollution Control Regulations (established in 1993). WHO standard is used as the standard of drinking water in the country.

(3) Policy for Environment

The environmental purviews of the Ministry of Lands, Natural Resources and Environmental Protection encompass wide terrain such as wild animals, forest usage, land usage, origins of mine and origins of healthcare. Development projects in every sector are obligated to conduct an EIA after establishment of environmentally related environmental protection and pollution protection laws and regulations.

(4) State of Environment and Audit on Environment such as Monitoring, etc.

There are several concerns about environment in Zambia such as deforestations by farmland development, decrement and demises of wild animals by poaching and aquatic contamination by industrial development in urban area. Additionally, air and water pollutions, deforestations, degradation of soil and waste disposal in respect of mining activities in the Copper Belt.

(5) International Cooperation, etc.

The Environmental Protection and Prevention of Pollution Act was established under the scheme of Environment Support Program run by the World Bank in 1990.

3.2.5 State of Mine Pollution and the Potential

(1) Mine Environment

There are two major mine environmental issues: pollution around copper mines and related facilities in the Copper Belt and issues arising from the abandoned lead mine and related tailings in Kabwe (Photo 3.9 and 3.10). Blacksmith Institute, an environmental organization in US, designated the abandoned Kabwe Pb-Zn Mine as one of the top ten polluted sites in the world (Blacksmith, 2009).

Photo 3.9 Smelter of Mufulira Mine in Copperbelt in Northwest of Kitwe City

Photo 3.10 Remain of Drainage of Kabwe Pb-Zn Mine (Soils around the mine are polluted)

(2) Occurrence and Potential of Mine Pollution

The mine pollution at Kitwe in Copper Belt is rising with SO_2 gas and metal elements being the chief contaminants.

Abandoned Pb-Zn Kabwe Mine was operated by ZCCM (Zambia Consolidated Copper Mines Limited) until early 1990s. Pollution from the mine emanated from spreading discharged water directly from underground to surface and also by spreading dust with metal elements from the tailings to surrounding areas causing soil and water contamination.

(3) Damage Situation of Mine Pollution

These concerns are well recognized as pollution by not only the government but also inhabitants of the district and the country. In Kitwe located in the Copper Belt, the residents living near the Kafue River, which flows thorough mine sites, are avoiding drinking this water. Additionally, several metal elements over the standard limit were detected in soils and crops around the mines and related facilities (Etter et al., 2012, Kribek et al., 2012, and so on).

Around the Kabwe Mine, the residents living nearby are not growing crops along the old mine drainages, along the downstream and around tailings. Domestic newspaper such as Lusakatimes occasionally reports on these issues.

(4) Handling for Mine Pollution

Government is conducting works to reuse of discharged water and is improving facilities as a mitigation plan. In the plan, Mines Safety Department, ZEMA and private sectors are enforcing collaborative audit and monitoring works to promote mitigation.

The audit carried out visually looks at the condition of the mining related facilities, discharged water and flue gas. Since there are no specific guidelines and procedures for the audits and monitoring for mine operations ZEMA conducts its work under the related law and the generalized conditions contained therein.

(5) Mitigation Plan for Mine Pollution

Government is conducting works to reuse of discharged water and is improving facilities as a mitigation plan.

(6) Monitoring around Mine Pollution Site

Mines Safety Department, ZEMA and private sectors are enforcing collaborative audit and monitoring works in mines. However, the result of these works are confidential.

The audit including monitoring is conducted by Mine Safety Department at Kitwe and ZEMA at Ndra. However, the management is poor due to the large number of sites, limited staff and the non-availability of techonology. Hence, resulting in poor and unreliable results.

In the abandoned Kabwe Mine, ZCCM is responsible for the management as the owner. Their progress with the environmental management has not been clarified.

(7) International Cooperation, etc.

There is no international support to reduce the mine pollutions.

3.2.6 Mine Safety

(1) Laws, etc. relating to Mine Safety

The Mines and Minerals Development Act (established in 2008) governs all mining practises. The act also stipulates the mining safety regulation which is derived from previous mine safety regulation enacted policy, the explosive regulation was also established in 1978.

(2) State of Mine Safety

Minor earthquakes and rock falls underground, washout of tailings dam and blackout in mine facilities are major safety concerns. The blackout incident at Nchanga Copper Mine in 2011, during which over 200 staff were stranded underground for a few hours is a fairly recent example.
Labor disputes occasionally at the mines. Labor strike at Luanshya and Kansanshi Mine in the Copper Belt are latest disputes during which the strike continued for several days stopping operations.

(3) International Cooperation, etc.

There is no international support to reduce the mine pollutions.

3.2.7 Present State of Human Resources Development and Request for Technical Training

(1) Present State of Human Resources Developing

There is no system concerning human resources development. Engineers are obtaining their skills via on the job training. There have been requests to participate in human resource development programs such as long-term training in Japan by JICA.

(2) International Cooperation, etc.

JICA has conducted seminars, short-term training and capacity development for the mineral resources development to support the Geological Survey Department. JOGMEC and other overseas agencies also provide support.

26 geologists (2 geologists in 2013) have participated in a short-term remote sensing training conducted by the JOGMEC Geologic Remote Sensing Center in Botswana.

(3) Request on Technical Training in Japan

Related departments are highly interested in undertaking long-term training in Japan. The technical contents which they want to acquire are as follows,

(Mines Development Department)

Technical items requested for:

- new technology for mining and mining management techniques
- Request for support from JICA: participation in the training hosted by JICA
- Training target person: several mining engineers in charge of monitoring works of mine operation

(Mines Safety Department)

Technical items requested for:

- methods for monitoring and management of mine environments such as discharged water, soil and air around mine area
- Request for support from JICA: participation in the training and donation of equipment for mine environment by JICA
- Training target person: several mining engineers in charge of monitoring and audit works for mine environment

(Zambia Environmental Management Agency)

Technical items requested for:

- methods for monitoring and management of air pollution, management of abandoned mine, management of mine discharged water, monitoring of air around mine area, monitoring and management of radioactive ray and re-evaluation of EIA
- Request for support from JICA: participation in the training hosted by JICA
- Training target person: several environmental engineers in charge of monitoring and audit works for mine environment

(Geological Survey Department)

Technical items requested for:

- methods for mineral resources exploration and environmental research based on hydrologic geology
- Request for support from JICA: participation in the training hosted by JICA
- Training target person: several geologists in charge of mineral resources exploration and hydrologic geologist in charge of hydrogeological exploration

3.3 Malawi

3.3.1 Outline of Malawi

(1) Current State of National Affairs and Economic Indicator in Malawi

The current state of national affairs and the economic indicator of Malawi are shown below:

- Area : 118,000 km^2 (Approximately total area of Hokkaido and Kyushu of Japan, refer to Figure 5.1).
- Population : 15,380,000 people (in 2011, WB).
- Capital City : Lilongwe (Population: Approximately 1,900,000 people in 2008).
- Races : Bantu people (Chichewa, Tumbuka, Ngoni and Yao).
- Languages : Chichewa and English (Official language), and others.
- Major Industries : (Agricultural Products) Tobacco, maize, tea, cotton, nut, coffee, etc. (Industrial Products) Textile, soap, shoes, sugar, beer, matches, cement, etc.
- GNI (Gross National Income): US$ 4,430 million (in 2011: WB).
- GNI per person : US$ 360 (in 2011: WB).
- Rate of Economic Growth: 4.3 % (in 2011: Malawi government).
- Price Increase Rate: 7.6 % (in 2011: Malawi government).
- Total Amount of Trade: Export: US$ 1,663 million.
  Import: US$ 2,220 million (in 2011, estimated by CIA).
- Major Export Goods: Tobacco, black tea, clothing, textiles, sugar, cotton, coffee, nut, etc.
- Major Trading Partner (in 2011: estimated by CIA):
  - Export : Canada (12.4 %), Zimbabwe (8.9 %), Germany (8.8 %), South Africa (8.4 %), China (6.1 %).
  - Import : South Africa (31.0 %), India (10.6%), Zimbabwe (9.4 %), China (8.7 %), Tanzania (5.7 %).
- Currency : Malawi Kwacha (MWK).
- Exchange Rate : US$ 1 ＝ 410 MKW (in November, 2013).
- General Situation of Economy:

  Malawi is an agricultural country with 80%of the workforce in the agriculture sector. Agricultural produce such as tobacco, tea and sugar make up eight out of ten of the entire export volume. For this reason, foreign currency earnings of Malawi are easily affected by international market conditions of agricultural prices. In view of this, the challenge for Malawi is to reform economic structures and to ensure other sources of foreign currency acquisition.

  Based on the above situation, Kayelekera uranium mine commenced operation in 2009. Its production rate is approximately 1,500t/y of ore and its ore reserves are calculated to be 11,000t. The mine is located in the northern part of the country. It is predicts that the rate of GDP of the mining sector would reach 20%. The economical behavior deserves attention.

- Major Donor Country (in 2009, DAC): UK, USA, Norway, Japan, Germany, etc.
- Records of International Cooperation and Assistance by Japan:
    (1) Onerous Financial Assistance (~2010, JICA) : ¥ 33,149,000,000 (Japanese Yen)
    (2) Gratuitous Financial Assistance (~2010, JICA) : ¥ 55,979,000,000
    (3) Technical Cooperation (~2010, JICA) : ¥ 34,526,000,000
- Local Administrative District: 3 Regions (Northern, Central and Southern) and around 20 Districts (Refer to Figure 5.1)

(2) State of Nature

a. Geographical Features

Republic of Malawi is located in the southeastern part of the Africa Continent and in the southern edge of the African Great Rift Valley, sharing borders with Mozambique, Zambia, Botswana and Tanzania. The capital city is Lilongwe and the largest city is Blantyre.

The topography of the country is predominantly highland. The country is somewhat an elongated shape with the width being 90 to 160km from east to west and length of approximately 900km from south to north. Water bodies such as lakes and rivers occupy 1/5 of land area. Lake Malawi alone takes up almost 20% of land area (Figure 3.12).

(Google)

Figure 3.12 Country of Malawi and Administrative Division

b. Geological Features and Mineral Deposits

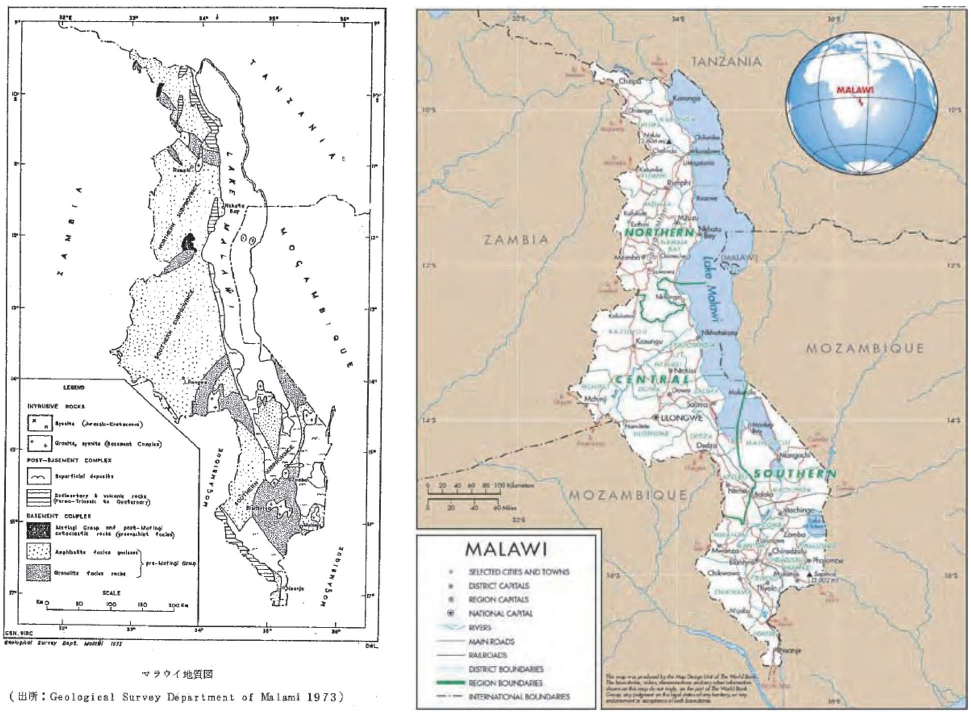
Geology of Malawi comprises of crystalline schist, paragneiss and granulite, which belong to granite and amphibolite ficies as a part of Mozambique Belt formed in Late Precambrian to Early Paleozoic age. Granulite facies in the rocks mostly consists of hypersthene granitic rock and olivine sillimanite graphite siliceous schist. Amphibolite facies consists of biotite gneiss and amphibolite. These base rocks contain lots of Ca and Mg, and are rich in K and Si in the northern part of the country. Parts of the base rock in the central to northern part of the country are covered by sandstone of Proterozoic as an unconformity.

Late Precambrian and Precambrian granite intrudes above basements. In the Jurassic era, there were activities of basaltic magma in southern part of the country, with basaltic dikes intruding to the basement and basaltic lava erupted. During the Jurassic to Cretaceous era, alkaline and carbonatite rocks formed near the surface where rocks are distributed as volcanic necks and intrusions. This area is known as Chilwa Alkaline Province (Figure 3.13).

In terms of mineral deposits, Malawi has three main heavy sand deposits and related organizations have been prospecting this. Among these, Tengani deposit has reserves of 108t ore containing ilmenite. Mpyukyu/Kachulu deposit located in Lake Chilwa basin, has reserves containing ilmenite of 48 million tons, zirconium of 30 million ton and rutile of 0.1 million. Monkey Bay, Salima and Unga deposits are located at the beach at the shores of Lake Malawi.

INCO has been prospecting for cooper and nickel mineralization hosted by pyroxine amphibolite which is deposited in the basement rocks in the northwestern part of Lilongwe.

In regards to rare metals, Chilwa Island in Lake Chilwa has been attracting attention for occurrences of Nb, which is located in the southern part of Malawi. In addition, carbonatite including apatite and pyrochlor is distributed in Tundulu in the southern shore of Lake Chilwa. Another carbonate body with strontianite and monazite is distributed in Kangankunde Hill near Balaka. These occurrences are attracting attention for Sr and Ce resources in the country (Figure 3.13).



マラウイ地質図

（出所：Geological Survey Department of Malami 1973）

(JOGMEC, 2005)

Figure 3.13　Geology and Distribution of Ore Deposits of Malawi

c.　Climate

Malawi has a tropical monsoon climate and the weather is cool due to the country's location in the highlands. May to October is the dry season. Annual amount of precipitation in the country is over 2,000mm, however, lowlands in southern parts of the country has relatively low rainfall, close to 800mm.

3.3.2　The First Site Investigation

(1)　Time Schedule on Site Investigation

The First Site Investigation in Malawi was carried out for five days from November 18 to November 22, 2013.

The time schedule on the first field investigation carried out is shown in Table 3.10.

Table 3.10 Time Schedule on First Site Investigation in Malawi

No	Month/ Day	Time	Place	Item of Work	Persons met
1	Nov./17 (Sun)	-	Johannesburg (South Africa) - Lilongwe (Malawi)	Travelling.	-
2	Nov./18 (Mon)	- 11:00 - 15:00 - 16:00 -	Lilongwe: JICA Office Policy and Planning Section, Ministry of Mining Environmental Affairs Department	 Courtesy and meeting on investigation. Courtesy and meeting on investigation. Meeting and interview.	 Assistant Representative and other related staffs Principal Economists Senior Inspector
3	Nov./19 (Tue)	 9:00 - 14:00 - 16:30 -	Lilongwe: Mines Department, Ministry of Mining Conference Room of Ministry of Mining Directorate of Occupational Safety and Health	 Interview, discussion, obtained information, receipt of the questionnaire, etc. Seminar. Meeting.	 Senior Mining Engineer and Mining Engineer Ministry of Mining, Mines Department, Geological Survey Department and Environmental Affairs Department Attendees: 7 persons from Malawi Senior Inspector
4	Nov./20 (Wed)	 10:00 - 14:00 - 15:30 -	Lilongwe: Policy and Planning Section Directorate of Occupational Safety and Health Environmental Affairs Department	 Interview, discussion, receipt of the questionnaire, obtained organization, etc. Interview, discussion, receipt of the questionnaire, etc. Receipt of the questionnaire, etc.	 Senior Mining Engineers Director and Senior Inspector Senior Inspector
5	Nov./21 (Thu)	 8:30 - 13:30 - 14:00 -	Lilongwe: Lilongwe Geological Survey Department Mines Department	 Arrangement of information by investigation. Interview, discussion, obtained organization, etc. Discussion, obtained information of Act and Regulations.	 Geologist Senior Mining Engineer
6	Nov./22 (Fri)	 9:00 - 15:30 - 16:30 -	Lilongwe: Outer of Lilongwe Environmental Affairs Department JICA Office	 Had a look small-scale mines and aggregate mines. Discussion, obtained organization chart. Report on outlines of investigation.	 Mining Engineer Senior Inspector Assistant Representative
7	Nov./23 (Sat)	-	Lilongwe:	Arrangement of information by investigation.	-

(2) Governmental Organizations Concerned

The organizations and offices which the delegation visited and the governmental organization, department, division, etc. related to the field investigation are as follows:

Place where the Delegation visited to:
- JICA Malawi Office

Relating Governmental Organization, Directorate, Department, etc.:
- Ministry of Mining: Policy and Planning Section
- Ministry of Mining: Mines Department

- Ministry of Mining: Geological Survey Department
- Ministry of Environment and Climate Change: Environmental Affairs Department

(3) Holding of Seminar

The seminar at Malawi was held at a meeting room in Ministry of Mining on 19 November. There were seven participants in the Seminar including one mining engineer from Mines Department, one economist and one geologist from Policy and Planning Section of the Ministry of Mines, three geologists from Geological Survey Department and one environmental engineer from Environmental Affairs Department (Photo 3.11 and 3.12).

At begin the seminar, Mr. Tomitani, Assistant Resident Representative of JICA Malawi Office, greeted the participants and spoke of the importance of this seminar and this study being a good opportunity for the mining sector of Malawi. After the speech, the study team gave their presentation which consisted of three files. The participants were very interested in the presentations.
In the seminar, the participants strongly requested for Malawi to be selected as a second investigation site of the study, because of there is no procedure for monitoring and audit with respect to mine environment in Malawi.

The Study team asked about the relationship between the government and private sector with respect to management and monitoring after the closure of Kayelekera Uranium Mine. The participants informed that the management should be done based on the EIA plan approved.
However, the government is concerned about the management and monitoring of uranium mine after its closure.

Photo 3.11 Interview with Policy and Planning Section, Ministry of Mining

Photo 3.12 Seminar at Ministry of Mining (Seven participants.)

(Explanatory Leaflet, etc.)
The seminar was carried out using the projector of conference room. Presentation materials used

in the seminar were:

1) Investigation in Africa - Explanation on Background of JICA: Activities of JICA, and
2) Investigation in Africa - Explanation on Mine Environment and Safety, Environmental pollution caused by mining and its countermeasures, etc. in Japan, and
3) Investigation in Africa - Explanation on Japanese Experiences for Sustainable Mining in respect to Mine Environment and Safety.

(Questions and Answers)

There are questions and answers session produced the following:

- Rules applicable to the government and private sector with respect to the management and counter measure for abandoned mines in Japan
- Method of management of the mine in case the owner becomes bankrupt
- Organization of environment-related government body in Japan
- Time of construction of treatment facility during mining
- Criteria to select investigation sites for 2nd study in countries
- Detail of long-term training in Japan

Table 3.11 List of Attendees to Seminar

No	Name	Organization / Division	Position
1	Stewart Ngalonde	Geological Survey Department, Ministry of Mining	Geologist
2	Buernett J.W. Msika	Department of Mines, Ministry of Mining	Mining Engineer
3	Patrick M. Nyirenda	Environmental Affairs Department, Ministry of Lands, Natural Resources and Environmental Protection	Environmental Engineer
4	Fumuyane Gondwe	Geological Survey Department, Ministry of Mining	Geologist
5	Gift Tsokonombwe	Geological Survey Department, Ministry of Mining	Geologist
6	James J. Namalima	Policy and Planning Section, Ministry of Mining	Economist
7	Chimwemwe Bandazi	Policy and Planning Section, Ministry of Mining	Environmental Engineer
8	Buernett J.W. Msika	Department of Mines, Ministry of Mining	Mining Engineer
9	Takeshi Tomitani	JICA Malawi Office	Assistant Resident Representative
10	Yoshimitsu Negishi	JICA Study Team	JICA Study Team
11	Hirohisa Kobayashi	JICA Study Team	JICA Study Team

3.3.3 Policy and State on Mineral Industries

(1) Directorate/Department and Organization in Charge

Mines Department of Ministry of Mining is conducting audit and monitoring works for mine operation, environment and safety (Figure 3.14). The department is not in charge of licensing procedure for EIA. However, they are carrying out EIA audit and monitoring with the Environmental Affairs Department and also their regional offices. The Commissioner for Mines and Minerals is a department for mineral resources exploration and is not in charge of tasks for mine environment and safety (Photo 3.13 and 3.14).

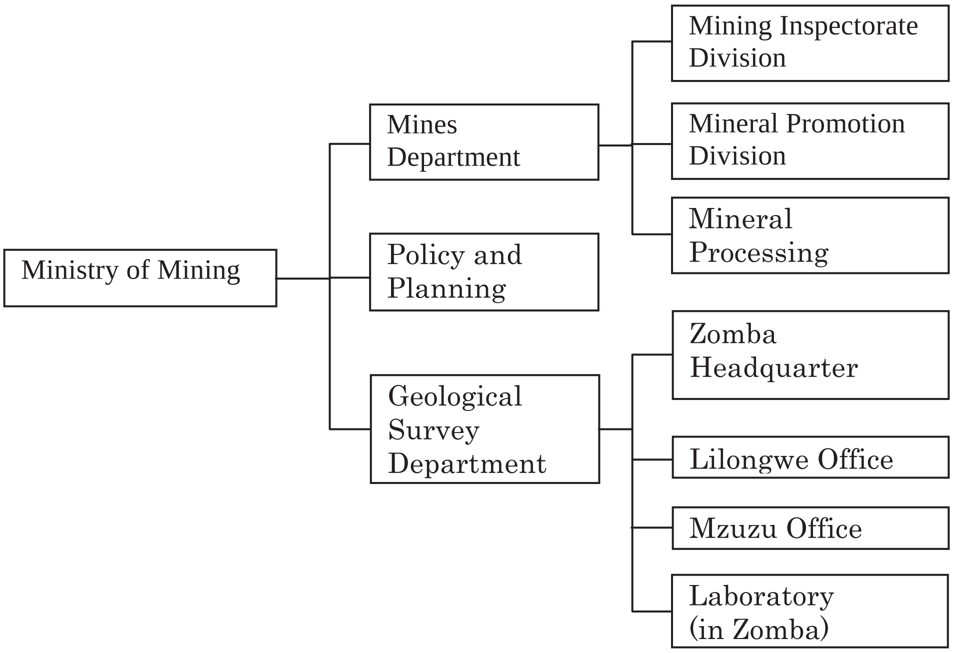


Figure 3.14 Present Organization Chart of the Ministry of Mining

Photo 3.13 Interview with Mining Inspectorate Division, Ministry of Mining (The Division is conducting audit and monitoring in respect to mining activities.)

Photo 3.14 Interview with Director for Directorate of Occupational Safety and Health, Ministry of Labor and Vocational Training

(2) Laws, Acts and Regulations relating to Mining Industries

Related laws and policies for mining in Malawi are the Mine and Minerals Act (established in 1981), the Mine and Minerals Policy (established in 2012) and the Atomic Energy Act (established in 2011). Relevant guidelines and procedures are not done by the mining sector.

Related laws and regulations for the mine environment are the Environmental Management Act (established in 1996), Mines and Minerals Policy (established in 2012) and the Environmental Management Policy. These have not been revised so far. Additionally, relevant guidelines and procedures are not done by the environmental sector.

International standards for water and air are used, for example, that of WHO because there are no national standards for these fields so far.

(3) Policy for Mining Industries

The mining sector contributed only 2% of Malawi's GDP in 2011. For this reason, mining is an important matter for government policy to accelerate mineral resources development. Based on this, the Mines Department embarked to revise the existing Mine and Minerals Act which was established in 1981, and also to create a law for oil exploration and development.

Moreover, Geological Survey Department commenced to carry out detailed airborne geophysics, to upgrade geological maps and mining cadaster, and to establish a geological data center for activate explorations.

In terms of revision of laws, description about royalty on the existing Mine and Minerals Act is not clear at the moment. For example, the actual royalty rate for Kayelekera Uranium Mine is 1.3% for three years from the initial year and increase to 3% after the third year. These rates are thought of as relatively low rate in comparison with other countries.

(4) State of Mining Industries

There are few operating mines in Malawi and there is no base metal mine such as copper. The target minerals to mine are coal, uranium, limestone, gems and aggregates. The relative maximum scale mine is Kayelekera Uranium Mine which started operating on 2007 and is an open pit mine. Mchenga Coal Mine is also a relatively large scale mine among these. There are coal mines such as Eland Mine and Kaziwiziwi Mine where the mines are operated by underground style. There are uranium and coal mines located in northern parts of the country (Table 3.12).

On the other hand, Shayona Limestone Mine, Tundulu Phosphate Mine, Chimwadzulu Gem Mine and other aggregate mines exist as medium-small scale mines in the country. Among these mines, limestone mines are located in the central part of the country, gem mines located in the south of Malawi Lake and aggregate mines located around Lilongwe.

Rare earth exploration in southern part of the country and oil and gas exploration near Malawi Lake have been activate in recent explorations. Current explorations are shown in Table 3.13.

(5) Role of Organization in Charge of Geology and Ore Deposits

Geological Survey Department falls under the Ministry of Mining as does the Mines Department. The main office for the department is located in Zomba. Lilongwe Office and Mizuzu Office are the local offices. The number of geologist in the department are 10 in Zomba Head Office, 3 in Lilongwe Office, 2 in Mizuzu Office and 2 in Ministry of Mining in Lilongwe. Their main tasks are to carry out geological mapping and mineral resources exploration in the country. However, their actual work in the office is to assemble existing geological information and related data. The department is not in charge of mine environment yet.

(6) International Cooperation, etc.

The mining sector such as the Mines Department has been funded by WB and EU program so far. However, there is no specific support program for the mine environment.

Geological Survey Department was supported by JICA through geological and mineral information upgrading project from 2012 to 2013 and dispatched long-term experts from 2009 to 2012. BRGM are conducting airborne geophysics from 2012. The survey will be finished by 2014 and the data will be used for the interpretation of mineral resources prospect. After the interpretation, mineral resources exploration projects will be launched supported by the French. In addition, China is also preparing mineral exploration projects in the country.

Fifty five geologists (7 geologists in 2013) have participated in the remote sensing training program in Botswana Remote Sensing Center.

Table 3.12 List of Operating Mines

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
1	Kayelekera	PALADIN ENERGY Ltd (100) (Australia)	575km north of Lilongwe	U	OP	2009 -	1500 t/y	U_3O_8	-	-
2	Mchenga	Mchenga Coal Mines Ltd.	Rumphi District	Coal	UG	? -	0.72 Mt/y	coal	-	-
3	Kziwiziwi	Kaziwiziwi Mining Company	Kziwiziwi	Coal	?	? -	0.25 Mt/y	coal	-	rock ejection from the wall 1 killed
4	Lufira	Eland Coal mining Co	Lufira coalfield	Coal	?	? -	0.25 Mt/y	coal	-	-
5	-	Ilomba Granite Company Ltd.	Chitipa District	Dimension stone	OP	? -	NA	stone materials	-	-
6	-	Granite Ltd.	Mzimba District	Dimension stone	OP	? -	NA	stone materials	-	-
7	-	Mzimba Gemstone Mining Cooperative Society Ltd.	Mzimba District	Gemstone	OP	? -	NA	amethyst, aquamarine, garnet and tourmaline	-	-
8	Nyala Mine	Nyala Mines Ltd.	Chimwadzulu Hill	Gemstone	OP	? -	300 Piece 150 Piece	ruby sapphire	-	-
9	Livwezi Mine	Shayona Cement Corp.	Livwezi	Ls	OP	? -	0.80 Mt/y	limestone	-	-
10	Tundulu Mine	Optichem Ltd.	Tundulu	Phosphate	OP	? -	NA	phosphate	-	-

Table 3.13 State of Exploration in Malawi (JOGMEC)

Stage	No	Name of Project	Kind of Elements	Proprietor, etc.
F/S	1	Kanyika	Nb, U, Ta, Zr	Globe Metals and Mining Ltd.(100)
Drilling	2	Kangankunde	La	Lynas Corp Ltd.(100)
	3	Livingstonia	U	Resource Star Ltd.(80) Globe Metals and Mining Ltd.(20)
	4	Songwe Hill	La	Mkango Resources Ltd.(100)
Geo-physical	5	Machinga	La, Nb, Ta, U, Zr	Globe Metals and Mining Ltd.(80) Resource Star Ltd.(20)
Preliminary	6	Ilomba Hill	U, Nb	Resource Star Ltd.(90) Nyalihanga Enterprises Ltd.(10)

3.3.4 Environmental Policy and State of Environment

Environmental Affairs Department, Ministry of Environment and Climate Change has been conducting permit approval works for EIA and audit works for EIA monitoring at operating mines. Environment Impact Assessment and Inspection Section (EIAS) is in charge of the works in the department. The audit and monitoring works is a collaborative work with the Mines Department.

There are no equipment and analytical instruments in the department. The staffs in the department rely on visual observation for monitoring and audit works. There is a plan to lay out these stuffs. However, the arrangements are pending due to insufficient budget in the department. Related guidelines and procedures are not set up in the department as well, so their work is carried out, abiding by the existing laws and regulations.

(1) Organization in Charge of Environment

Organization of the department pertaining to the environment is as follows:

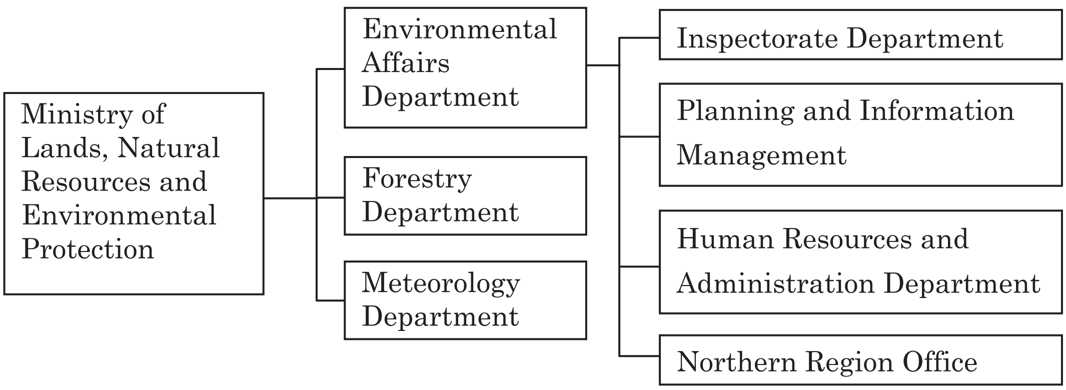


Figure 3.15 Present Organization Chart of the Ministry of Environment and Climate Change

(2) Laws, etc. relating to Environment

The laws and regulations for the mine environment are the Environmental Management Act (established in 1996), the Mine and Minerals Policy (established in 1996) and the Environmental Management Policy. There are no guidelines and procedures set up for the environment so far. Under these laws and regulations the standard such that of WHO are used as criterions for air and water.

Currently the concerned department does not have any standards for environmental activities of their own and neither have they prepared to revise any of the laws and regulations

(3) International Cooperation, etc.

UNEP has supported to create a guideline for environmental management. JICA is sending one environmental expert to configure environmental data in the concerned department. There has not been any overseas aids specialized in mine environment so far.

3.3.5 Environmental Policy and Condition

(1) Mine Environment

Serious mine pollutions has not occurred so far. However, dust in coal and aggregate mines, mine drainage in coal mine, topographic change and drainage in small-scale mines are of potential concern (Photo 3.15 and 3.16). There is no pollution due to acid mine drainage at the moment.

Photo 3.15 Abandoned Aggregate Mine in South of Lilongwe (Inhabitants are mining illegally.)

Photo 3.16 Local inhabitants are crushing the stone (The stone price is approx. ¥2,500/t)

(2) Occurrences and Potential of Mine Pollution

Kayelekera Uranium Mine is of potential concern for the mine environment. Mine pollution at the tailing, waste and drainage has not been reported from the start of operation to date.However, audit and monitoring works by inspectors is challenging since they rely on visual observation, monitoring for uranium is not included in the analytical items conducted by the owners and the method of management procedures for mines after closure is not clear at the moment. Government departments for environmental audit are very understanding about these issues; however, there are no activities to be solved yet.

Beside the above concerns, dust and the mine drainage at Mchenga Coal Mine, dust at Terrastone Quarry, are recognized as potential mine pollution. Inspectors of departments are conducting audit and monitoring to decrease the potential level, however, the method of the inspection is visual observation.

(3) Damage Situation of Mine Pollution

Noticeable mine environmental problems around mines have not been reported, however, there are several claims from people living around mines about dust at coal and aggregate mine and washout of soil at small-scale mines are increasing.

(4) Handling of Mine Pollution

As a counter measure to the claim in the aggregate mines, mine owners are performing watering to reduce dust at the mines. No counter measures for soil washout on the periphery and the topography at small-scale mines has been taken.

3.3.6 State of Countermeasure and Monitoring for Mine Pollution

(1) Mitigation Plan for Mine Pollution

As a counter measure to the suggested potential pollution in the aggregate mines, mine owners are performing watering to reduce dust at the mines. Also, the Mines Department and Environmental Affairs Department continue with auditing and monitoring at the mines.

(2) Monitoring around Mine Pollution Site

Monitoring work in the mine environment is conducted by the Mines Department and Environmental Affairs Department. However, they rely on visual observations.

(3) International Cooperation, etc.

There is no support to reduce potential of mine pollution from overseas agencies to the related department so far.

3.3.7 Mine Safety

(1) Laws, etc. relating to Mine Safety

Related laws and regulations for mine safety are the Mine and Minerals Act (established in 1981), the Mine and Minerals Policy (established in 1996), the Occupational Health, Safety and Welfare Act (established in 1997), the Atomic Energy Act (established in 2011) and the Explosives Act (established in 2005). Related guideline and procedure has not been set up so far.

(2) State of Mine Safety

Rock falling in shaft and underground at Mchenga Coal Mine and explosion and rock falling in quarry mines are the accidents that have occurred in mines. Mine workers and government inspectors lost their lives in these accidents. Additionally, the government has begun to record the number of people impacted form radioactive materials which discharge from uranium mines.

(3) International Cooperation, etc.

There is no aid from overseas agencies or collaborative project with overseas sectors in respect to mine safety.

3.3.8 Present State of Human Resource Development and Request for Technical Training

(1) Present State of Human Resources Development

There is no original system about human resource development. Engineers are obtaining their skills by on the job training. Currently, there are requests to conduct human resource development programs such as long-term training in Japan by JICA.

(2) International Cooperation, etc.

JOGMEC and JICA have been coordinating seminars and short-term training of the Geological Survey Department as an international cooperative aid for development of human resources. On the other hand, Australian government commenced an aid for the human resources in respect to mine safety from 2011.

55 geologists (7 geologists in 2013) participated in a short-term remote sensing training by JOGMEC Geologic Remote Sensing Center in Botswana.

(3) Request on Technical Training in Japan

Related departments have strong interest in attending long-term trainings in Japan. The technical contents which they want to acquire are:

(Mines Department)

Technical items intended to acquire: method for management and audit of operating mine, expert knowledge of monitoring for operating mine and expert knowledge of monitoring for EIA and mine environment

Request for support from JICA: engineering resource development for operating mines, audit and monitoring of mine environment and safety, donation of handy equipment for environmental monitoring and donation for analysis center and analytical instrument

Training target person: several mining and environmental engineers in charge of audit and monitoring works of mine operation

(Environmental Affairs Department)

Technical items intended to acquire: technical knowledge of audit and monitoring procedure for mine environment and EIA

Request for support from JICA: engineering resource development for auditing and monitoring, donation of handy equipment for environmental monitoring, and participation in the training hosted by JICA

Training target person: several environmental engineers in charge of monitoring and audit works

(Directorate of Occupational Safety and Health)

Technical items intended to acquire: technical knowledge of auditing and monitoring for mine safety

Request for support from JICA: engineering resources development for auditing and monitoring of mine safety, donation of handy equipment to measure personal impact, and support for creating guidelines and procedures for auditing and monitoring in respect to mine safety

Training target person: several technical inspectors in charge of monitoring and audit works

3.4 Botswana

3.4.1 Outlines of Botswana

(1) Current State of National Affairs and Economic Indicator in Botswana

The current state of national affairs and the economic indicator of Botswana are as shown below:

- Area : 582,000 km^2 (Approximately 1.5 times of Japan, refer to Figure 3.16).
- Population : 2,030,000 persons (in 2011: the World Bank).
- Capital City : Gaborone (Population: Approximately 230,000 persons in 2011: Estimated by the national census).
- Race(s) : Setswana people (73 %), Kgalanga people (11 %), etc.
- Language(s) : English and Setswana (National Language).
- Major Industries: (Agricultural Products): Sorghum bicolor, maize, (Stock breeding): Cattle, Sheep, (Minerals): Diamond, copper, nickel and coal, (Industrial Products): Textile fiber products and processed foods.
- GNI (Gross National Income): US $ 15,180 million (in 2011 : the World Bank).
- GNI per person : US$ 7,470 (in 2011 : World Bank).
- Rate of Economic Growth: 5.7 % (in 2011 : World Bank).
- Price Increase Rate : 10.7％ (in 2011: World Bank).
- Total Amount of Trade: Export: U S$ 6,458 million
  Import: US$6,275 million (in 2011 ; EIU).
- Major Export Goods: Diamond, Cu, Ni, textile fiber products and beef.
- Major Trading Partner (in 2011: estimated by CIA).
  - Export: U.K. (55.3 %), South Africa (13.2 %), Norway (9.3 %), Israel (5.2 %).
  - Import: South Africa (72.4 %), U.K. (9.2 %), China (5.4 %), Israel (1.8 %).
- Currency : Pula.
- Exchange Rate : US$ 1＝8.2 Pula (in April, 2013).
- General Situation of Economy:

  The economy of Botswana after independence was wholly dependent on the export of beef its basic industry, however, the economy rapidly developed since the discovery of diamond deposits in 1967. Botswana is the first place where diamond industry started in the world, and it occupies approximately 30% of GDP, 56.3% of total exports in 2009 and approximately 50% of Government revenue, and thus the economy of Botswana performed a world prominently high economic growth at the average rate of 9% during these 30 years. On the other hand, the government of Botswana is planning to carry out the diversification of industries in order to reduce the economic dependence on diamond, and also making efforts to achieve employment creation, rectification of difference of wage, etc. preparation of regional infrastructures, etc.
- Major Donor Country (in 2010, DAC): USA, Japan, France, Sweden and Germany.
- Records of International Cooperation and Assistance by Japan:

(1) Onerous Financial Assistance (until 2011, JICA): ¥13,246 million (¥: Japanese Yen).

(2) Gratuitous Financial Assistance (until 2011, JICA): ¥4,157 million.

(3) Technical Cooperation (until 2,011, JICA): ¥5,654 million.

- Local Administrative District: 9 districts (Refer to Figure 3.16).

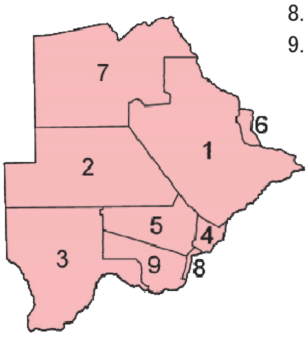
(2) State of Nature

a. Geographical Features

Botswana is located at the southern part of Africa and is a landlocked country surrounded by South Africa at the south side, Namibia at the west and north sides, Zimbabwe at the east side and by Zambia at the north side. The capital city of Botswana is Gaborone.

Botswana is surrounded by highlands at its circumference, the distance to sea is 700 km, and is located at the center of a basin where a wide plain is spread out. The altitude above sea level is more or less 1,000 m.

Central part of Botswana is covered with the savannah and shrubs and grasses grow sparsely in the savannah, and Kalahari Desert covers most of the western part of the country. The Cubango River, flows out to Angola in the northwest of the country, it flows stagnantly and forms wide and huge Okavango wetlands in the northern parts. Most of southern parts of the country forms desert, and Limpopo River and Morobe River form the border between this country and South Africa.



1. Central District
2. Khanzi District
3. Kalahari District
4. Kgatleng District
5. Kweneng District
6. Northeast District
7. Northwest District
8. Southeast District
9. Southern District

(Google image)

Figure 3.16 Republic of Botswana and its Administrative District

b. Geological Features and Mineral Deposits

Two thirds of the country area is covered with aeolian sediments in Kalahari Desert, and exposed rocks can be seen in one third of the country area in the east, and the Archean Shield is mainly distributed in this exposed area (Figure 3.17). Kaapvaal Block is distributed at the southern part of Botswana and Zimbabwe Archean Blocks are distributed at the northern part, and the area between these has Limpopo Mobile Belt distributed.

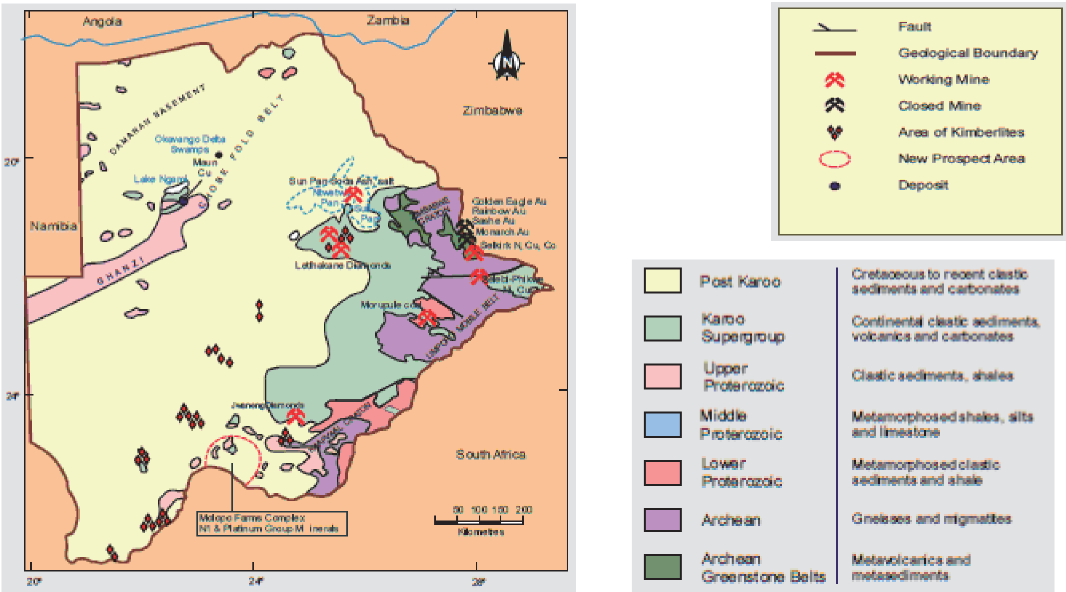
The eastern part of Botswana has the distribution of Zimbabwe Archean Block in the north from Limpopo Mobile Belt as the border and rocks of Kaapvaal Archean Block distributed at the south from the same border. Zimbabwe Archean Block is characterized by granitic gneiss, intrusive granite, ultramafic rocks, etc., and is known as Granite-Greenstone Belt. This Greenstone Belt has the mineralization of Au and base metals (Cu, Ni) deposits. There are layers of weakly deformed metamorphic volcanic rocks of Archean and layers of sedimentary rocks overlap each other at the upper part of Kaapvaal Block and it would be expected that the mineralization of Au and U might originate therein.

The central and the northwest parts of Botswana are composed of complex series of orogenic zones located between Kaapvaal-Zimbabwe Block in the east and Angola Block in the far north (towards Namibia and Angola).

Volcanic sedimentary layers from Late Proterozoic to Middle Proterozoic are distributed in the southern parts of Botswana, and many large mafic rocks intrude therein similar to Bushveld Complex producing Platinum Group Elements (PGE) and Cr in South Africa.

Kimberite which is known as the stratum, from which diamond originates, does not intrude into the specific formation and its activities have been well known for a considerable period in the geological history of Botswana.

Several important mineral deposits has formed during geological progresses (Figure 3.18).It is recognized that the mineralized ores of Au Ni, Cu, Pb and Zn exist in Zimbabwe Block, and Limpopo Mobile Belt includes Cu, Ni and small amounts of precious metals as well as other nonmetals. Mn, Fe and asbestos are present in Transvaal Supergroup. PGE and chromite ore deposits have been discovered in Molopo Farms Complex. Kheis Mobile Belt and Magondi Mobile Belt at the central part and at the northwestern part of Botswana has large amounts of Cu, Pb, Zn, Ag and small amount of Au mineralized ores. There may be possibilities of the existence of hydrocarbon traps in the deep sedimentary basin discovered in the Damara Area. There are large scale deposits of coal and diamond (i.e. lamprophyre, etc.) in Karoo Supergroup. Huge mineral deposits of soda ash and rock salt exist at the Makgadikgadi Basin in the center of Botswana.



(JOGMEC, 2008)

Figure 3.17　Geological Features of Botswana

(JOGMEC, 2008)

▲ Mine

■ Smelter

Figure 3.18　Distribution of Major Mineral Deposits in Botswana

c. Climate

Although Botswana is located in lat. 18 to 27 °S and the most parts of the country is in the subtropical zones, the annual average temperature is 20 to 23 °C, similar to that of the temperate zones since the country is located at highlands and the height above sea level is approximately 1,000m.　However, the change in atmospheric temperature is large. Temperatures in summer are torrid but the temperature may become below freezing in some days of winter. There are two seasons, i.e. the rainy season in summer, November to March, and the dry season in winter from June to August, dry season continues from May to September with severely dried atmosphere.

3.4.2 The First field Investigation

(1) Time Schedule on Field Investigation carried out

The first field investigation in Botswana was carried out for five days from November 18 to November 22, 2013. The time schedule on the first field investigation carried out is as shown in Table 3.14.

Table 3.14 Time Schedule on First Field Investigation Carried out in Botswana

No	Month/Day	Time	Place	Item of Work	Remarks
1	Nov./17 (Sun)	-	Johannesburg – Gaborone (Botswana)	Travelling	
2	Nov./18 (Mon)	8:30 ～ 10:00 ～ 14:00 ～ 16:00 ～	Gaborone： MEWT MMEWR JICA Office Japanese Embassy	Courtesy, meeting on Questionnaire, Seminar, etc. Courtesy, received Questionnaire, and Seminar, etc. Courtesy, meeting on Investigation, etc. Courtesy, a brief explanation on the investigation	Department of Environment, 2 officers in charge of EIA. Chief of Directorate of Mines, and one officer Chief of office and others Ambassador and 1 officer
3	Nov./19 (Tue)	9.00 ～ 14:00 ～ 17.30	Gaborone： Geological Survey Office Seminar at Department of Environment	Courtesy and Meeting on Questionnaire, etc. Seminar	Dep. of Environment and Geology Directorate of Mines, Department of Environment, Geological Survey Center: Attendees：11 persons
4	Nov./20 (Wed)	9:00 ～ 10:00 ～ 11.30 ～ 14.00 ～	Gaborone： SADC Department of Environment Department of Waste Control, NEWT Directorate of Mines	Collection of Information Meeting on Questionnaire, obtaining relating Laws, etc. Collection of information on waste control, etc. Meeting on Environment and Safety, etc. in Mines	Specialist dispatched by JICA Officer in charge of EIA and others Officer in charge of Control Officer in charge of environment and safety
5	Nov./21 (Thu)	9:00 ～ 14:00 ～ 16:00 ～	Gaborone： Directorate of Mines Department of Environment JOGMEC Office	Meeting on present state of explore, standard of environment, etc. Receipt of Questionnaire, etc. Courtesy. And brief explanation on the investigation, etc.	Officer in charge of environment and safety/ 2 officers in charge of EIA Chief of office and 2 officers in charge
6	Nov./22 (Fri)	9:00 ～ 10:00 ～ 14:00 ～	Gaborone： Department of Waste Control Department of Environment JJICA Office	On the standard of environment, etc. Received the demand for training of human resources, etc. Report on Investigation Brief report on the Investigation	Chief of the Department of waste control Officer in charge. Representative and Other staffs
7	Nov./23 (Sat)		Gaborone– Johannesburg – Harare (Zimbabwe)	Travelling	

(2) Governmental Organization subject to the Investigation and Place visited

The organizations and/or offices which the delegation visited and the governmental organization, department, division, etc. relating to the field investigation are:

Place where the Delegation visited to:

- Japanese Embassy in Botswana, and
- JICA Office in Botswana.

Relating Governmental Organization, Department, Division, etc.:

- Department of Protection and EIA, Department of Environment, Department of Waste Control of the Ministry of Environment, Wild Life and Tourism (MEWT),
- Directorate of Mines, Ministry of Mines, Energy and Water Resources (MMEWR), and
- Analysis Section, Department of Environment and Geology, Department of Geological Survey.

(3) Collection of Questionnaire

The questionnaire was prepared during the preparation work in Japan, and distributed to Directorate of Mines in the Ministry of Mines, Energy and Water Resources and Department of Environment in the Ministry of Environment, Wild Life and Tourism, as the major relating organization, through the JICA Office in the country concerned prior to the First Site Investigation.

Although it was scheduled that the answered questionnaires would be collected at the time when the delegation visited the relating organization for the site investigation, discussions on the answer of questionnaires were done at the visit and the questionnaire was collected later since most of respective organizations had not completed the preparation of answers by that time. Hence, the answered questionnaires were collected later. Total three sets of answers of questionnaires, i.e. one set from Mine Environment and Safety Section, Directorate of Mines, and two sets from Department of Environment were collected.

(4) Holding of Seminar

The seminar was held at the conference room (20 persons could be accomodated) in Department of Environment of the Ministry of Environment, Wild Life (MEWT) and Tourism for approximately 3.5 hours from 14:00 to 17:30 on November 19, 2013. The attendees were 11 persons in total, i.e. 2 persons from Directorate of Mines in the Ministry of Mines, Energy and Water Resources (MMEWR) and 6 persons from Department of Environment MEWT, and 1 person from Department of Environment and Geology in Department of Geological Survey as well as 2 persons from Remote-sensing Training Center of JOGMEC (Photo 3.17 and 3.18).

During the seminar, attendees had strong interest in the historical occurrences of environmental pollution caused by mining, the state of harm and/or damage suffered, actual examples of counter measures and considerations and cares on mine environment in Japan as well as the procedures of human resources development of JICA.

Photo 3.17 Attendees to Seminar

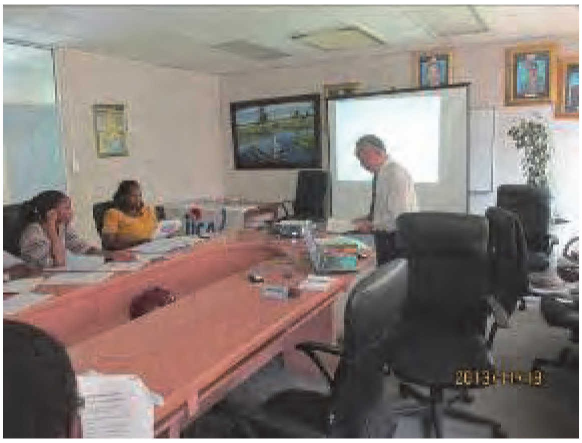


Photo 3.18 State of Seminar

(Explanatory Leaflet, etc.)

The seminar was carried out by using the projector in the conference room. Presentation materials used in the seminar were:

1) Investigation in Africa–Explanation on Background of JICA 131105: Activities of JICA
2) Investigation in Africa–Explanation on Mine Environment and Safety: The said matter, environmental pollution caused by mining and its counter measures, etc. in Japan

(Questions and Answers)

The session was held for about one hour and detailed explanations and discussions were made for queries on the damage of vegetation due to exhaust gas from the smelter in Ashio Mine, the state, harm and damage by pollution, for example, diseases such as “Itai-itai” caused by cadmium poisoning, etc., as well as on the relation to the cost of counter measures, the system of environmental control and the scheme of human resources development.

Table 3.15 List of Attendants to Seminar

No	Name	Organization / Division*	Position
1	Lechani Motshwaraksole	MEWT, Department of Environmental Affairs	Senior officer
2	Judith Maimla	MEWT, Department of Environmental Affairs	Officer
3	Ingrid Otukile	MEWT, Department of Environmental Affairs	Chief officer
4	Christopher Nkala	MEWT, Department of Environmental Affairs	Officer
5	Kgaodi	MEWT, Department of Environmental Affairs	Officer
6	Lesego Seakanyens	MEWT, Department of Environmental Affairs	Officer
7	Kinalemang Charles	MMEWR, Directorate of Mines	Senior Engineer
8	Kebonyemotse Bontshitswe	MMEWR, Directorate of Mines	Assistant Officer
9	Oarabile Seiphemo	Department of Geological Survey	Geologist
10	Takashi Ooka	JOGMEC Botswana Geologic Remote Sensing Centre	General Manager
11	Junichi Ishikawa	JOGMEC Botswana Geologic Remote Sensing Centre	Geologist

*: MEWT : Ministry of Environment, Wild Life and Tourism.
MMEWR : Ministry of Mines, Energy and Water Resources.

3.4.3 Policy and State on Mineral Industries

(1) Department and Organization in Charge

The organization that is in charge of supervisory and administrative work for all mines in Botswana is the Directorate of Mines in the Ministry of Mines, Energy and Water Resources (MMEWR), provided that the permit on the exploration of mining is given by and under the control of Department of Geological Survey, and vice-ministers or the like in respective ministries. The division of mineral materials is composed of Directorate of Mines, Department of Geological Survey and Department of Mineral Resources, and the Directorate of Mines consisting of the Department of Mine Administration and Development, the Department of Internal Audit and that of General affairs. The Department of Mine Administration and Development mainly manages and controls the exploration and mining of mine areas, mining technology, monitoring and environmental control (including the counter measures for environmental disruption caused by mining), etc., and the Department of Internal Audit is in charge of the supervision of the management and control of mines as well as field inspection, etc. And Department of Geological Survey is in charge of the deposit exploration fields and Department of Mineral Resources' main role is to promote mine development (Figure 3.19).

The chief of Directorate of Mines and the office in charge of mine environment and safety cooperated to carry out of this investigation (Photo 3.19).

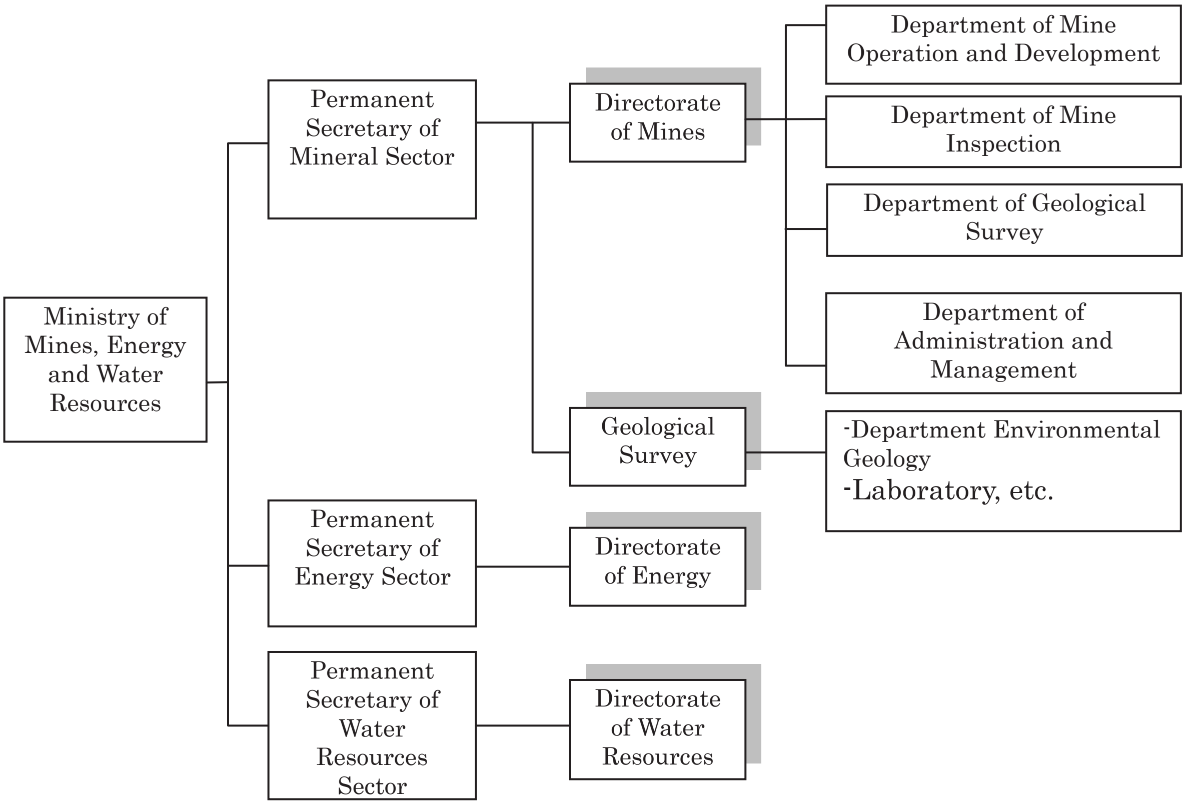


Figure 3.19 Present Organization Chart of Directorate of Mines in MMEWR

Photo 3.19 Personnel in charge of Management and Control of Mines

(2) Laws, Acts and Regulations relating to Mining Industries

The Directorate of Mines of the Ministry of Mines, Energy and Water Resources cooperated in gathering information on the related laws, acts and regulations.

Laws, acts and regulations in regard to mining industries in Botswana are presented in Table 3.16.

Table 3.16 Laws, Acts and Regulations for Mining Industries in Botswana

No	Laws, Acts, etc. relating to Mines	Year enacted	Outlines
1	Law of Mines, Crushed Stones and Machinery (old) Mining Law	1973	-Discontinued due to enactment of New Mining Law
2	Law of Mines and Minerals (new) Mining Law	1999	-Right of mineral ownership, mining license, permit for exploration, obligation for protection of environment, etc, are stipulated by this law. -License for closing mines/mining is to be given in accordance with this law. -The handling of explosives, etc. is stipulated by this law. -There are provisions for closing mines therein. -Others
3	Act of Mines, Crushed Stones and Machinery	1978	-Regulations and rules in regard to mining.
4	Law of Gunpowder	1962	-Laws in regard to the handling of explosives.
5	Regulation of Gunpowder	1970	-Regulations and rules in relation to the handling of explosives.

(Laws, Acts, etc. relating Mine Environment)

The laws, acts, regulations, etc. regarding mine environment have been enacted as shown below. Most of the laws, acts, etc. in relation to mine environment have revised, however, detailed regulations, rules and guidelines has not been enacted yet.

- Environmental Impact Assessment Act,
- Atmospheric Pollution Prevention Act,
- Water Contamination Prevention Act,
- Noise Prevention Act,
- Wastes Management and Control Law, and enforcement regulations and guidelines relating to the same,
- Laws, etc. relating to water,
- Environmental Standard for Air Quality,
- Environmental Standard for Water Quality,
- Environmental Standard for Groundwater Quality,
- Environmental Standard for Noise, and
- Environmental Standard for Drinking water.

Soil Contamination Prevention Law, etc. has not been enacted yet.

The following information has been obtained about the laws, acts, regulations, etc. concerning EIA in Botswana,

- All of the matters of Environmental Impact Assessment (EIA) relating to mine development is under the control of the Ministry of Environment, Wild Life and Tourism (MEWT), and EIA Reports for the project of mine development is to be submitted to the MEWT, and examined on the specified field by the section in charge in Directorate of Mines in the MMEWR and the result is to be provided to the MEWT as their comments. "Permit on Environment" will be granted upon MEWT's approval, provided the general examination procedures are successfully completed.

- The EIA for mine exploration stage may be required depending on kinds, scale, etc. of the exploration, and the major procedures of the same are similar to those stated above.
- The monitoring of environment during mine development has to be carried out by the person who carries out the project and the result is to be submitted to the Directorate of Mines and it is assessed by the Department of Mine Control and Development. The standard for assessment is the “Environmental Standards” established by the MEWT.

(3) Policy on Mining Industries

The main mining industry in Botswana is the production of diamond, and the amount of diamond produced as personal ornament is placed ranked first in the world (32% in market share) and that for industrial use is placed fourth in the world (11% in market share) in 2010. The production of copper and nickel also plays an important role for the national economy though the production scale is rather small in comparison with that of diamond. According to the Doing Business Report (in 2011) of the World Bank, the business environment of Botswana is placed 53rd among 183 countries in the world, and placed third among African countries after Mauritius and South Africa. According to the Fraser Report in 2012, Botswana is placed 17th (among 93 countries) as the supreme country for investment. The investment environment of Botswana is receiving higher evaluation in the world stage, and receipt of foreign investment towards mining industries of diamond, copper, nickel and coal is becoming the driving force for the high rate of economic growth. In April, 2008, Ian Khama was inaugurated as the President, and a steady policy for mining industries was successively promoted for investment of mining development and the exploration of mines.

The government is promoting the development of manufacturing industries, financial business and tourism for diversification of domestic industries in order to extricate the system dependence on mining industries. The mining industry sector contributed to the GDP in 2006, however, it decreased to 34.7 % in 2010. At this stage, the tenth (10th) National Development Scheme is being promoted in Botswana for the purpose of continuing sustainable economic growth until 2016. In this scheme, the production of high value-added products and the strengthening of downstream sectors in mining industries is also included.

(4) State of Mining Industries

The growth rate of the GDP in Botswana was 7.2% in 2010, an increase from 4.9% in 2009. The income by exportation in Botswana was US$4,600 million in 2010. Majority of this was from export of diamond, valued at US$3,200 million, which is approximately 70% of total export income as aforementioned. Second major contributor was the export income of copper and nickel, valued at US$620 million (13.5%). The growth of GDP was at a high rate of 5.7% in 2011, drawn from the growth of mining sectors, important one being diamond.

Mowana Copper Mine is the first large scale copper mine which commenced its operation in 2008, the operation of the mine was suspended temporarily in January, 2009 due to the worldwide decline in copper price, decrease of demand and difficulty to procure the working capital amounting US$15 million. After that, the operation of the mine restarted in August, 2009 from the recovery of copper price, and the improvement of crushing equipment and floatation facilities is being carried out aiming to achieve full production.

The northern area is attracting a great deal of attention at Karahari Copper Belt, Boseto project for copper and silver has commenced its production from June 2012. Although the present production capacity is planned at 36,000 tons/year of copper and 34 tons/year of silver, it is scheduled to increase its capacity in future up to 50,000 tons/year of copper. The feasibility study (F/S) is being carried out by Ghanzi project in this area.

There are 16 mines operating currently, i.e. 8 metal mines (Cu, Ni, Co and Au), one soda ash mine, 6 diamond mines and 1 coal mine. A new Cu-Ni mine has been developed in 2012 and currently operates in the New (Karahari) Copper Belt. Sites for exploration of mine areas are widely distributed in whole country, particularly exploration areas are distributed all over the area along the New Copper Belt.

There is one Ni smelter which belongs to BCL Mine.

List of operating mine and that of smelter/refinery in Botswana are as shown in Table 3.17 and Table 3.18 respectively.

Table 3.17 List of Operating Mines (1)

No	Name of Mine	Proprietor (ratio)	Location	Kind of Mineral	Mining Method	Period of Mining	Produced Amount of Mining (Products)*1		Environmental Issues	Safety Issues
1	Selebi-Phikwe	Bamangwato Concessions Ltd. (BCL)	Selebi Phikne	Ni, Cu, Co	UG, OP	1994 -	3.0 Mt/y 0.03 Mt/y 0.025 Mt/y 400 t/y	ore metal metal metal	- Problem of mine water:	
2	Tati (Phoenix) Ni･Cu	Norilsk Nickel (85), Botswana Government (15)	Francistown	Ni, Cu Co	OP	1964 -	3.6 Mt/y 0.015 Mt/y 9000 t/y 100 t/y	ore metal metal metal	- Problem.	
3	Bobonong	Masa Precious Stones (Pty.) Ltd.	Bobonong, east of Selebio Phikwe	Ni, Cu, Co	OP	-	4.0 Mt/y	ore		
4	Mupane	African Copper Plc. (100)	Near Francistown	Au	?		3100 t/y	ore	- Waste water.	
5	Mowana	?	?	Cu	OP	-	4100 t/y	metal		
6	Lobatse	Lobatse Clay Works (Pty.) Ltd.	Lobatse, 70 km south of Gaborone	Clay	OP	-	0.5 Mt/y			
7	Makoro	Makoro Brick and Tile (Pty.) Ltd.	Makoro, 10 km northwest of Gaborone	Clay	OP	-	0.2 Mt/y			
8	Moruple Coal	Morupule Colliery (Pty) Ltd. [Anglo American Corp. of South Africa Ltd. (ACC)and related firms,(93.3)]	Moruple, 270 km northwest of Gaborone	Coal	OP	-	1 Mt/y			
9	Jwaneng	Debswana Diamond Co. (Pty.) Ltd. [Government (50), and De Beers Centenary AG (50)]	115 km west of Gaborone	Dia	OP	-	12000 TC/y			
10	Orapa	Debswana Diamond Co. (Pty.) Ltd. [Government (50), and De Beers Centenary AG (50)]	375 km west of Gaborone	Dia	OP	-	13000 TC/y			
11	Lethakane	Debswana Diamond Co. (Pty.) Ltd. [Government (50), and De Beers Centenary AG (50)]	350 km west of Gaborone	Dia	OP	-	1000 TC/y			

*1 MT: million tons, TC: Thousand Carat.

Table 3.17 List of Operating Mines (2)

No	Name of Mine	Proprietor (ratio)	Location	Kind of Mineral	Mining Method	Period of Mining	Produced Amount of Mining (Products)		Environmental Issues	Safety Issues
12	Damtshaa	Debswana Diamond Co. (Pty.) Ltd. [Government (50), and De Beers Centenary AG (50)]	220 km west of Gaborone	Dia	OP	-	670 TC/y			
13	Tawapong	Tswapong Mining Co. (Pty.) Ltd. [De Beers Prospecting Botswana Ltd., (85), Government, (15)]	275 km west of Gaborone	Dia	OP	-	3 TC/y			

Table 3.18 List of Smelters and Refineries

Name of Smelter/Refinery	Proprietor (ratio)	Kind of Mineral	Amount of Production*2	Issues on Environment and/or Safety
Selebi-Phikwe Smelter	Bamangwato Concessions Ltd. (100)	Cu mat (1,000 t) Ni mat (1,000 t) Co mat (1,000 t)	14 29 340	- Exhaust gas. - Groundwater was contaminated.

*2: Estimated production in 2010 (based on each metal).

(5) Role of Organization in Charge of Geology and Ore Deposits

Geological Survey of Botswana prepares and manages geological maps and maps of mineral deposits, grants and manages licenses for exploration of mineral deposits.

The Geological Survey of Botswana as well as analysis section of the Environment and Geological Center supported to this investigation to gather information.

(Department of Geological Survey)

The Geological Survey of Botswana, as an external Department of MMEWR, is involved in the geological survey and the preparation of geological maps. This organization is composed of the Hydro-geological Department, Department of Regional Geology, and Environmental Geology Department and Project Section of Geological Information Center, as well as support sections such as Chemical Analysis Section, Map Preparation Section, etc.

In this investigation, officers in charge from Environmental Geology Department and from Chemical Analysis Section cooperated with and supported the delegation.

As to the organization relating to geological survey, there is the Department of Geological Survey also in MMEWR, and this organization is composed of Physical Exploration Department, Ore Dressing Examination Section and Drilling Department, etc. The Geological Survey of Botswana is an organization originally separated from the Department of Geological Survey through the reorganization of the same and it is said that the Department of Geological Survey in whole is scheduled to be shifted to the Geological Survey of Botswana in the near future.

(Chemical Analysis)

Analysis is being performed at the analysis section in the Geological Survey of Botswana and in the Department of Waste Contamination Control of MEWT. The following information regarding analysis being carried out at respective sections has been obtained:

- Analysis section in Botswana Department of Geological Survey: Most heavy metals are analyzed herein, however, the analysis of As, Hg and Se cannot be carried out at this stage. The analytical instrument used is AA-MASS which has a higher accuracy as it is in compliance with the international environment standards. As to the period of analysis, it is desirable to have a more efficient timeframe. (It takes slightly longer time: two weeks or longer).
- Analysis section in Department of Waste Contamination Control : Considerable kinds of substances in heavy metals cannot be analyzed. The analytical instrument being used is Atomic Absorption Spectrophotometer (AA), however, it is expected that the analysis of As, Hg, etc. will possibly be done from next year since the analytical instrument is expected to be substituted by the graphite furnace type. The analysis of organic substances is also carried out in this section, and it is desired that this department will be considered for carrying out analysis

work for this investigation.

- MEWT is to carry out cross-checking of the result of analysis described in the monitoring report submitted in every three months from the project team including respective mining companies against the result of analysis carried out in their own analysis section.

(6) International Cooperation, etc.

Although it is noticed that the international cooperation has not happened in the sector of mines and that of geology and mineral deposits, training at Botswana Geological Remote-sensing Center has been carried out by JOGMEC in recent years, and 70 persons in total have been trained therein during the past five years (2 persons in 2013). Trainees are mainly dispatched from the Geological Survey of Botswana and Directorate of Mines.

3.4.4 Policy on Environment of Organization in Charge and State of Environment

(1) Organization in Charge of Environment

The Ministry of Environment, Wildlife and Tourism (MEWT) is composed of the Department of Environment, the Department of waste and Contamination Control, the Department of Forest Resources, the Department of Wild Life and National Park, the Department of Tourism and the Department of Meteorology, and is in charge of management, control and supervision of the environment of the country (Figure 3.20 and Photo 3.20).

The Department of Environment consists of Environmental Information Control Department, Planning and Policy Department, Education and Acknowledgement on Environment Department, Management and Control Department and Local Branch Offices (5 offices). The Environmental Information Control Department is mainly in charge of the environmental impact assessment (EIA).

The Department of Waste and Contamination Control is consists of Waste Management and Control Department, Contamination Control Department and Analysis Office, Management and Control Department. The Waste Management and Control Department is in charge of management and control of general industrial wastes, and Contamination Control Department is in charge of contamination control for specific cases including the contamination of atmospheric air, water and soil as well as hazardous issues of noise and vibration. Accordingly, the issue due to contamination and pollution in mines and its counter measures are to be performed by this department with cooperation of the Directorate of Mines.

During this Study, the Environmental Information Control Department in Directorate of Environment has mainly supported the Study team.

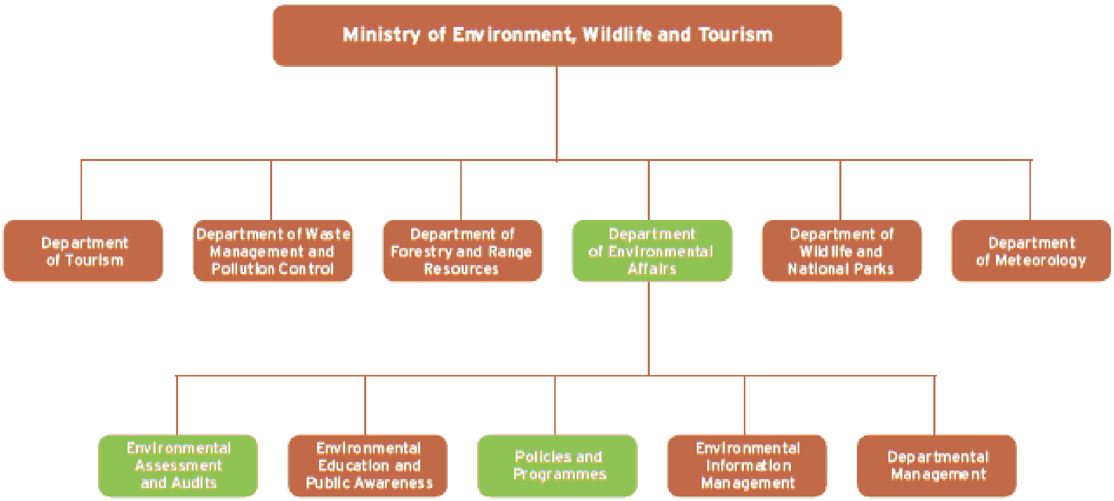


Figure 3.20 Organization of the Ministry of Environment, Wildlife and Tourism (MEWT)

Photo 3.20 Department and Department in Charge of Environment

(2) Laws, Regulations, etc. relating to Environment

a. Laws, Regulations, etc. on Environment

The following laws, acts, regulations, etc. have already been enacted.

- Environmental Impact Assessment Act,
- Atmospheric Pollution Prevention Act,
- Water Contamination Prevention Act,

- Noise Prevention Act,
- Wastes Management and Control Law, and enforcement regulation(s) and guidelines relating to the same,
- Laws, etc. relating to water,
- Environmental Standard for Air Quality,
- Environmental Standard for Water Quality,
- Environmental Standard for Groundwater Quality,
- Environmental Standard for Noise, and
- Environmental Standard for Drinking water.

(There is no Soil Contamination Prevention Law yet.)

b. Procedures of Environmental Impact Assessment (EIA)

Procedures of EIA in Botswana are as shown in Figure 3.21.

MEWT is in charge of all the matters of EIA relating to the development of mines and the report from the project for development of mines is to be submitted to the said ministry, and the review and examination on specialized field in the report are to be carried out by the section in charge of environment in the Directorate of Mines of the Ministry of Geology and Mines and the result is to be reported as its comments. Subsequently, the “Permit of Environment” is to be granted upon the approval by the MEWT through the general review and examination on overall matters as are the procedures.

Although the actual experience on EIA regarding mine development is few, there are many records on the execution of EIA at mine exploration phase.

The environmental audit of mine exploration phase may require a preliminary EIA depending on its scale, and the procedures of the said EIA are as similar as the above stated.

Figure 3.21 Process of EIA in Botswana

(3) State of Environment and Audit on Environment such as Monitoring, etc.

a. Response to Environmental Issue relating to Mines

The obligation to environment of mines is stipulated by "Law of Mines and Ore Minerals" (new Mining Law), and obligations require to prepare, to carry out EIA, environmental control plan, mine closing plan, monitoring plan, etc. as well as to solve issues prior to the commencement of exploration and mining work.

b. Monitoring relating to Mines

The monitoring at mine development is to be carried out by the person who executes the project, and the result of monitoring has to be submitted to the Directorate of Mines and is to be evaluated by the Department Mine Control and Development. The standards for evaluation on the same are in accordance with "Environment Standards" established by the MEWT.

3.4.5 Mine Environment

Environmental issues relating to mines in Botswana (environmental pollution caused by mining and the potential of the same) are shown in Table 3.19.

Table 3.19 Environmental Issue relating to Mines in Botswana

No	Name of Mine	Location	Kinds of Minerals	Environmental Issues	Safety Issues
1	Selebi-Phikwe	Selebi Phikne	Ni, Cu, Co	- Problem of mine water: Presently mine water is recycled within the mine site.-	
	Selebi-Phikwe Ni-Cu (Smelter)	elebi Phikne	Ni	- Exhaust gas (SO_2) - Groundwater was contaminated due to devastation of river bed caused from mining work of sands for smelting.	-
2	Tati Ni・Cu	Francistow n	Ni, Cu Co	- Problem., but the state is unknown.	
3	Mupane		Cu	- Waste water containing CN. - Affects the eco -system.	

Three operating mines have environmental disruption caused by mining, i.e. Selebi-Phikwe Mine and Mowana Mine have been confirmed. In addition to the above, Ni and Cu Smelter belonging to Selebi-Phikwe Mine also has environmental issues.

BCL Mine is a government managed mine and has issues of exhaust gas (SO_2) from Ni Smelter and is due to exploitation of sands for smelting. Also, there was an environmental issue of mine water and waste water from mineral dressing operation, however, the issue has decreased since all of such waste water is being recovered and recycled at present. The exhaust gas from smelter affects the vegetation, etc. in the surrounding areas. In addition, there are impacts on agricultural water and potable water caused by the devastation of riverbed due to exploitation of sands for smelting (approximately 360,000 tons /year).

In Mupane Mine, water containing cyanide from heap leaching pond leaked into downstream reservoir and impacted flamingoes, wild ducks, etc.

There are issues of danger, due to subsidence of suspended and/or closed mines such as the ruins of manganese mine in the west of the capital city Gaborone and the ruins of fox holes in gold mines in the northwest part of the country.

3.4.6 Mine Safety

As to mine safety in Botswana, the following information has been obtained:

- Matters regarding mine safety are included in Mines Law,
- There are no issues relating to mine safety at this stage, and
- The accidents in mines are as shown in Table 3.20, there are few serious accidents but no loss of lives until now.

Table 3.20 Accident occurred at Mines in Botswana

Year	Nos. of Accident Occurrence	Nos. of Fatal (death) Accident	Total
2008	55	3	58
2009	32	2	34
2010	57	3	60
2011	66	1	67
2012	36	4	40
2013*1	24	3	27

*2013: Data up to October.
* The disclosure of information on Accidents is duly performed.
* Protection of Natural Resources : Natural resources are protected by means of supervising and controlling illegal mining, etc.
* Others.

3.4.7 Present State of Human Resources Development and Demand for Technical Training

(1) State of Human Resources Development

The human resources development activities in MMEWR and in MEWT have not been actively carried out until now.

The support of human resources development provided to respective ministries from various foreign countries are:

- Directorate of Mines in MMEWR: There was training at SADC and a seminar.
  Also, several persons have gained experience from the training course by JICA.
- Department of Waste and Contamination Control in MMEWR: Many personnel have received the training course on solid wastes by JICA.
- Directorate of Mines in MEWT: Several persons have received the training course by JICA, JOGMEC (at Kosaka). Also, one person has received the training on remote-sensing by JOGMEC.
- Geological Survey of Zimbabwe : the "Department of Environmental Geology" was established by assistance from Germany. At that time, 3 persons visited Germany for training though this was only once. Further training in Germany has not been performed thereafter. Approximately 10 persons have received the training course of JOGMEC.

(2) Requests on Technical Training in Japan

Demands in regard to the development of human resources in the future from the Directorate of Mines and Department of Geology in the MMEWR and from the MEWT are listed below:

＊Long Term Training : 1 to 2 years (Including masters (MS) course)
＊Medium Term Training : 1 to 6 months
＊Short Term Training : 1 to 3 weeks

(Directorate of Mines in MMEWR)

Directorate of Mines in MMEWR is hoping for support for the development of human resources in regards to mine management and control, mine environment and safety.

- Mine Environment and Safety：2 persons（Short Term; 2 persons）
- Management and Control of Mineral Resources：3 persons（Short Term; 3 persons）
- Law of Mines and Preparation of Mining Policy：4 persons（Short Term; 4 persons）

(Directorate of Environment in MEWT)

As the Directorate has little experience in carrying out EIA, the support for development of human resources on the whole environmental affairs is strongly desired.

- Management and Control of Environment: 2 persons (Long Term; 2 persons)
- Environmental Impact Assessment: 2 persons (Long Term; 2 persons)
- Laws, etc. and policies on Environment: 1 person (Long Term; 1 person)
- Environment Assessment on Mines: 5 persons (Long Term; 5 persons: MS course)
- Monitoring and Auditing on Environment : 15 persons (Long Term; 5 persons: MS course, Medium Term; 10 persons)
- Strategic Environmental Assessment：15 persons (Medium Term; 15 persons)
- Method of Evaluation on Environmental Impact Assessment and Strategic Environmental Assessment: 15 persons (Medium Term; 15 persons)
- Policy on Environment and Environment Law：10 persons (Medium Term; 10 persons）
- GIS-Remote-sensing: 10 persons (Medium Term; 10 persons)
- Environmental Impact Assessment and Counter-measures to prevent Pollution caused by Mining：15 persons (Short Term; 15 persons)
- Mine Safety: 15 persons (Short Term; 15 persons)
- Management, Control and Planning on Environment: 15 persons (Short Term; 15 persons)
- Organization of Quality Control: 15 persons (Short Term; 15 persons)
- Urban Development Planning: 15 persons (Short Term; 15 persons)
- Waste management and Control Plan: 15 persons (Short Term; 15 persons)
- Restoration of Environment and Recovery of Mine Site: 15 persons (Short Term; 15 persons)

(Geological Survey of Botswana)

- Evaluation on Environmental Monitoring and Modeling: 1 person (Short Term; 1 person)
- Sampling Method and Analysis of Underground Water: 1 person (Short Term; 1 person)
- CCS-Clean Coal Technology: 1 person (Short Term; 1 person)
- Alternative Thermal Power Generation Technology: 1 person (Short Term; 1 person)
- Sustainable Mine Development: 1 person (Short Term; 1 person)
- GIS in Mining Field : 1 person (Short Term; 1 person)
- Method of Water Monitoring: 1 person (Short Term; 1 person)
- Advanced Counter measures to prevent Pollution caused by Mining: 1 person (Short Term; 1 person)
- Advanced Technology for Petroleum Development: 1 person (Short Term; 1 person)
- Modeling of Geochemical reaction: 1 person (Short Term; 1 person)
- Applied Environmental Geology: 1 person (Long Term; 1 person)
- Petroleum Geology: 1 person (Long Term; 1 person)
- Applied Geology: 1 person (Long Term; 1 person)
- Hydro-chemistry: 1 person (Long Term; 1 person)

3.5 Zimbabwe

3.5.1 Outline of Zimbabwe

(1) Current State of National Affairs and Economic Indicators in Zimbabwe

The current state of national affairs and the economic indicators in Republic of Zimbabwe (here-in-after called Zimbabwe) are shown in the following:

- Area : 390,000 km^2 (Slightly larger than that of Japan, refer to Figure 3.22).
- Population : 13,720,000 persons (in 2012; the World Bank).
- Capital City : Harare (Population: Approximately 1,460,000 persons in 2012).
- People : Shona people, Ndebele people and White people.
- Languages : English (Official Language), Shona Language and Ndebele Language.
- Major Industries : (Agricultural Products): Tobacco and Cotton, (Minerals): Pt, Cr, Asbestos, Ni and Au.
- GNI（Gross National Income）: US $ 9,310 million (in 2012: the World Bank).
- GNI per person : US$ 680 (in 2012: the World Bank).
- Rate of Economic Growth: 9.3 % (in 2011: Announced by the Government).
- Price Increase Rate : 3.5 % (in 2011: Announced by the Government).
- Total Amount of Trade: Export; US$ 3,934 million, Import; US$ 6,735 million (in 2011 ; Central Bank of Zimbabwe).
- Major Export Goods : Ni, Cotton Wool, Pt, Tobacco and Garden Crop.
- Major Trading Partner (in 2011: CIA):
  - Export : South Africa (54.2 %), EU (11.2 %) UAE (10.3 %), China (7.4 %).
  - Import : South Africa (50.2 %), USA (8.5 %), EU (8.4 %), China (6.2 %).
- Currency : Multiple currency system: US$ and South African Rand.
- General Situation of Economy : Since the latter half of 1990s, the economic issues of inflation, unemployment, poverty, etc. prevailed due to the weak governance and the failure of economic policy. This worsened due to the confusion caused by presidential election in 2008 and to the hyperinflation by the excessive issuance of banknotes. This extreme economical confusion was settled and some economic growth was recorded after 12 years as a result of the government introduceing the multiple foreign currency system (US$ and South African Rand) in January, 2009 and the inhibition of semi-financial activities, etc, as well as the cash budget compilation performed by the Central Bank under the government formed in February, 2009. However, the opaque situation of economy is still continuing due to the enactment of laws in relation to localization of capital and the huge amount of external debt, financial issues, etc.
- Major Donor Country (until 2010: DAC): USA, UK, Australia, Germany and Sweden.
- Records of International Cooperation and Assistance by Japan：
  （1）Onerous Financial Assistance (until 2011) : ¥38,065 million (Japanese Yen),
  （2）Gratuitous Financial Assistance (until 2011) : ¥55,631 million, and
  （3）Technical Cooperation (until 2011) :¥16,670 million.

- Local Administrative District：2 cities and 9 provinces (Figure 3.22).

1. Burlawayo City
2. Harare City
3. Manicaland Province
4. Mashonaland Central Province
5. Mashonaland East Province
6. Mashonaland West Province
7. Masvingo Province
8. Matabeleland North Province
9. Matabeleland South Province
10. idlands Province

（Google image）

Figure 3.22 Map of Zimbabwe and its Administrative Districts

(2) State of Nature

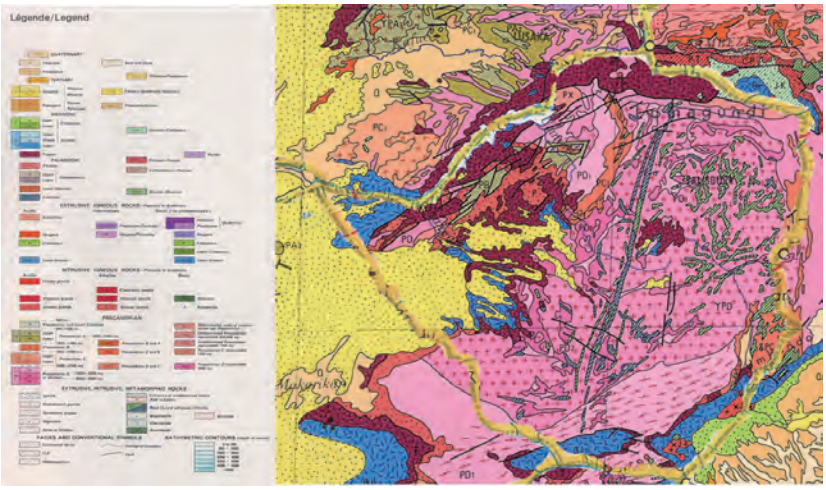
a. Geographical Features

The Republic of Zimbabwe is located at an inland area of southern part of Africa and is adjacent to Mozambique, Zambia, Botswana and South Africa. The capital city of the country is Harare.

Geographically, most of the country is plateaus and the eastern areas are mountainous zone. The lowest point of land in the country is at the confluence point of Runde River and Save River and the height above sea level is 162 m, and the highest point is at the top of Mount Nyangani having its altitude of 2,592 m above sea level.

b. Geological Features and Mineral Deposits

60 % of the country is covered with granite of Archean and greenstones and it is known that these strata may contain gold and/or base metals therein. The great dyke rock bodies are extended from south to north of the country and has divided this granite layer of Archean into two parts and it is known that the great dyke has world famous chromite deposits therein. It is known that the coal deposit is existing in the younger strata covering the area around the stratum of Archean as mentioned above (Figures 3.23, 3.24 and 3.25).



(JOGMEC, 2008)

Figure 3.23 Geological Features of Zimbabwe

(JOGMEC, 2008)

Figure 3.24 Distribution of Major Mineral Deposit in Zimbabwe

(JOGMEC, 2008)

Figure 3.25 Coal Resources in Zimbabwe

c. Weather

The weather in Zimbabwe is mostly tropical to subtropical with the highland areas experiencing more temperate weather. Rainy season continues from November to March.

3.5.2 First Site Investigation

(1) Time schedule

The first site investigation in Zimbabwe was carried out twice from November 25 to November 29, 2013 (5 days) and from January 19 to January 21, 2014 (3 days). Detailed time schedules are in Table 3.21 (1) and (2).

Table 3.21 Time Schedule on First Site Investigation in Zimbabwe

(1-1)

No	Month / Day	Time	Visiting place	Workings	Remarks
1	Fri, Nov 23		Gaborone - Johannesburg - Harare (Zimbabwe)	Travel	
2	Sun, Nov 24		Harare	Indoor works and preparation for following days	
3	Mon, Nov 25		Harare:		
		8:30 ~	JICA office	Courtesy call	G. Manager and a follower
		10:00 ~	Chamber of Mines of Zimbabwe (COM)	Courtesy call / Hand over questionnaires and request for response to them / Information gathering	Officer in charge of Mines and economy
		11:30 ~	Chemical laboratories	Information gathering	G. Manager and a follower
		14:00 ~	COM	Information gathering on mines and COM activities	Officer in charge of Mines and economy
4	Tue, Nov 26		Harare:		
		9:00~	Ministry of Mines and Mining Development (MMMD)/ Mining Development Authority	(Request form to Ministry of Foreign affairs of Zimbabwe)	(Received the request form)
		10:00~	COM	Information gathering on mines	Officer in charge of Mines and economy
		11:00~	COM	Information gathering on geology and mineral deposits	Deputy G. Manager
		14:00~	Bureau of Geological Survey	Request for meeting appointment	(Appointed date of meeting on Nov 28)
		16:00~	Mining Development Authority / Environment Management Agency	Courtesy call / Hand over questionnaires / Information gathering	Manager of Environment Division and 3 followers
		16:30~	Environment Services Division of EMA /MEW /Environment Services Authority of MEW	Courtesy call /request for response to questionnaires /Interpretation of purpose of the investigation	G. Manager of Environment Services Authority and a follower
5	Wed, Nov 27		Harare:		
		9:00~	COM	Information gathering on environment and mine safety	Officer in charge of Mines and economy
		10:00~	COM	Information gathering on mines	Deputy G. Manager
		15:00~	Bureau of Geological Survey /EMA /Environment Services Division of EMA	Information gathering on environment and regulations /Request for participation in the seminar	Officer in charge of Environment Impact Assessment (EIA)

Table 3.21 Time Schedule on First Site Investigation in Zimbabwe

(1-2)

No	Month / Day	Time	Visiting place	Workings	Remarks
6	Thu, Nov 28		Harare		
		9:30~	MMMD /Mining Development Authority	Courtesy call /Interpretation of purpose of the investigation /Request for response to questionnaires /Information gathering /Request for participation to the seminar	Under-secretary of Mining Development Authority and others
		14:00~ 16:00	MEW meeting room	Holding the seminar	Participation of 12 people from MEW, EMA, MMMD, and JICA
7	Fri, Nov 29		Harare		
		9:00~	EMA	Retrieval of response to questionnaires /Human resources development	G. Manager of Waste Management Authority and followers
		10:00~	MEW	Retrieval of response to questionnaires / Human resources development	Officer in charge of EIA
		14:00~	JICA Office	Brief report on the investigation	G. Manager of JICA and a follower
		16:00~	Embassy of Japan	Courtesy call / Brief report on the investigation	Ambassador and 2 followers
8	Sat, Nov 30		Harare - Johannesburg - Dubai - Tokyo	Travel (Return to Tokyo/Narita on Dec 21)	

Table 3.21 Time Schedule on First Site Investigation in Zimbabwe

(2)

No	Month / Day	Time	Visiting place	Workings	Remarks
1	Tue,Feb 18	-	Lusaka - Johannesburg - Harare (Zimbabwe)	Travel	
2	Wed,Feb 19	9:00 ～ 14:00 ～ 16:30	Harare: JICA Office Ministry of Mines and Mining Development (MMMD)/ Mining Promotion Development, Mining Engineering D.	Courtesy call and meeting Courtesy cal / questionnaires and request for response to them / information gathering	G. Manager and a follower Director of Department, Chief Engineer, Mining management officer
3	Thu,Feb 20	8:30 ～ 12:30	Harare: MMMD, Mining Promotion Development, Mining Engineering D.	Request for response to questionnaires /Information gathering concerning organization of the Ministry and local branches, Legislation, management system of mining, mining policy, mine environment, mine safety, mine pollution and measures, human development, etc.	Chief Engineer, Mining management officer
4	Fri,Feb 21		Harare: Site visit: Chinhoyi District, Shackleton Mine (sleeping mine)	Minied site, waste dump area,Tailings dam, Consentrator, smelter, etc.	Manager of Chinhoyi Branch Office, Manager of ZMDC in Chinhoyi, other 2 staff
5	Sat,Feb 22		Harare - Johannesburg - (Hong Kong) - Narita	Travel (Feb 23 Arrived)	

(2) Visited government departments for investigation and places visited

Places and Government departments visited

(Visiting places)

- Embassy of Japan in Zimbabwe.
- JICA Office in Zimbabwe.

(Governmental organizations visited for investigation)

- Ministry of Mines and Mining Development (MMMD) /Mining Development Authority: No face to face meeting with Undersecretary due to his absence.
- Directorate of Geological Survey.
- Chamber of Mines of Zimbabwe (COM).
- Ministry of Environment, Water and Climate /Environment Services Authority.
- ・Environment Management Agency (EMA) /Environment Services Division.

(3) Retrieval of questionnaires

The questionnaires had been designed and forwarded to the Japanese embassy for distribution to the relevant government bodies. This however, did not happen. Instead, the team had to conduct face to face interviews to get the required information. Some questionnaires were received back from Environment Services Authority of MEW and EMA.

(4) Seminar

The seminar was held for 3 and half hours from 14:00 pm until 17:30 pm on Nov 19 at a meeting room at the Environment Authority of Ministry of Environment, Wild Life and Tourism (MEWT). Eleven people in total participated; 2 from Mines Authority of Ministry of Mines, Energy and Water Resources (MMEWR), 6 from Environment Authority of MEWT, 1 from Environmental Geology Division of the Directorate of Geological Survey, and 2 from Training Center for Remote Sensing of JOGMEC (Photo 3.21 and 3.22, Table 3.22).

The seminar focused on topics such as historical cases of mining-induced environmental damages in Japan, their nature and magnitude, countermeasures, improved management of mine safety, and human resources development programs by JICA. These have attracted a keen interest from the participants.

Photo 3.21　Participants of seminar

Photo 3.22　Session of seminar

(Presentation materials)

The seminar went along with presentation of 2 files as itemized below:

1) JICA area studies of Africa - its background 131105: A part of JICA activities
2) Area studies of Africa - status quo of mine environment and safety: relevant cases in Africa, cases of mining-induced environment damages in Japan and countermeasures taken against them

(Q and A session)

Following questions were raised and followed by answers and discussions:

- Damages against vegetation caused by waste gas from a nearby refinery of Ashio copper mine.
- Mining-induced damages vs cost for countermeasures.
- Situation of pollution-induced cases such as "Minamata" and "itai-itai" diseases.
- Scheme for an environment management system and human resources development.

Table 3.22　List of Attendants to Seminar

No	Name	Organization / Division	Position
1	Irrin Kunene	MoEW, Directorate of Environment and Natural Resources	Director
2	Abu Z. Matiza	MoEW, Directorate of Environment and Natural Resources	Deputy Director
3	Aaron Chigina	EMA, Directorate of Environmental Management Services	Director
4	Petronella Shoko	EMA, Directorate of Environmental Protection	Director
5	Alleta Nyahuye	EMA, Section of Environmental Planning and Monitoring	Manager
6	Syaka Ochida	JICA Zimbabwe Office	Staff

(Abbreviation)

MEW: Ministry of Environment, Water and Climate (specifically, Environment Services Authority, a subordinate executive organization of MEW)

EMA: Environmental Management Agency (specifically, Environment Services Division, a subordinate executive organization of EMA)

3.5.3 Mining policy and status quo of domestic mining

(1) Department in charge of mining and overall organization

Administration structure in respect of mine and mine environment is shown in Figure 3.26.

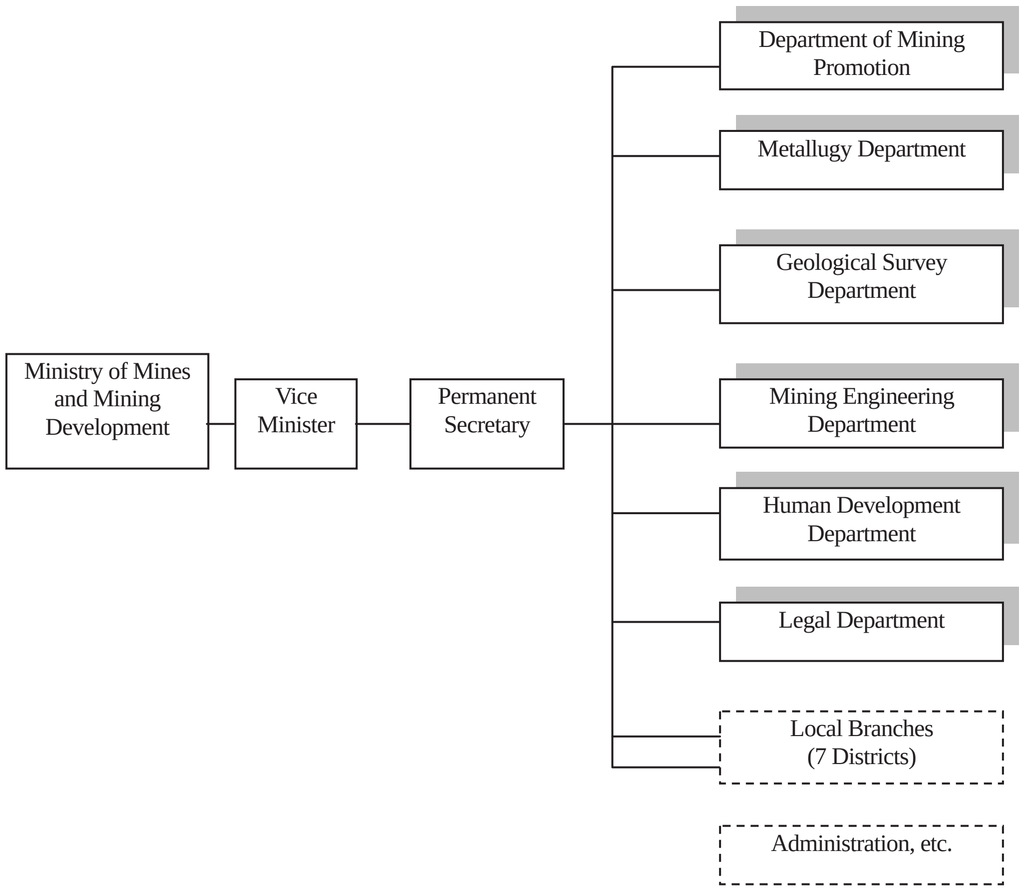


Figure 3.26 Outline of organization of Ministry of Mines and Mining Development

(Outline of MMMD)

MMMD is involved with all the matters on management of mining and its operation. Prospecting license is granted by MMMD in consideration of the comments put forward by the Directorate of Geological Survey which is supposed to scrutinize applications for prospecting license (Directorate of Geological Survey used to handle the management of prospecting licenses as well.).

Face to face meeting with Undersecretary of MMMD was cancelled in spite of prior appointment. This was due to his business trip and no alternative arrangement for a face to face meeting with a representative officer in charge was made. No information was forthcoming from MMMD on issues such as non-response to questionnaires, on-going reorganization of MMMD, mining regulations, status quo of existing mines, mining-induced damages, mine safety, request for human resources development including training programs. The status quo of mining and its associated damages was obtained from COM and Environment Management Agency and also from existing literatures.

MMMD is organized with its subordinate departments such as Mines Authority, Mining Law Management Authority, Mining Engineering Authority, Mining Promotion and Development Authority, Geological Survey Authority, Metallurgy Authority, and Administrative Division: Mining Authority administers and supervises mining concessions, Mining Development Authority handles promotion of mining industry, Geological Survey Authority puts much effort on construction of database for mineral resources, Mining Engineering Authority is in charge of equipment, explosives, and environment management of existing mines.

(2) Mine

There are 58 existing mines in operation for various mineral resources such as Au, Cr・Ferro-Cr, Fe, Mn, Cu, Ni, Co, Pt, P, diamond, asbestos, coal, limestone (cement), vermiculite. A number of mines are operating for Au and Cr. Most of the mines for Au are, however, small-scale.

Au and basemetals such as Cu, Pb, and Zn are distributed in a geological region called "Green Stone Belt" of Archaean on the geologic time scale and intrusive granite rocks while Cr, Ni, Co, and Pt are in "Great Dykes" which runs NNE-SSW through the central part of Zimbabwe (Figure 3.27).

Most of the mines are owned and run by private companies while Zimbabwe Mining Development Corp (ZMDC), a state-run company, is operating 8 mines; Shabanie Mine for Asbestos, Gaths Mine for Asbestos, Trojan Mine for Cu, Dalny Complex Mine for Au, Kwekwe Mine for Au, Shamva Mine for Au, Unki Mine for Ni, and Iron Duke Mine for Pyrite. In addition, there are 8 refineries for Cr, Ni, Cu, and Fe. Lists of the mines and refineries are shown in Tables 3.23 and 3.24, respectively.

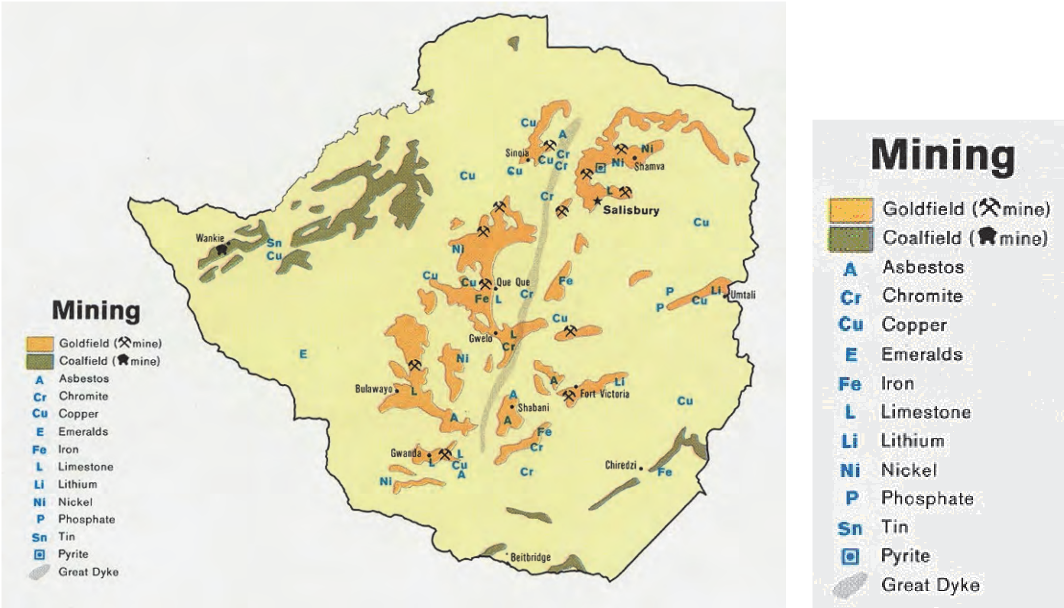


Figure 3.27　Location of mines

(3)　Mining Law and related regulations

Information on mining law and related regulations came through Mines Authority and Legal Division of MMMD.

- Mines and Minerals Law (1961):
  - ･All the minerals shall belong to President
  - ･Mining rights may be applied with Mining Commissioner　and Mining Application Board (MAB)
  - ･Minister of MMMD delegates its power to MAB which shall be made up of 11 members including Under-secretary of MMMD, Chief Mining Engineer of the government, Director of Metallurgy Authority, G. Manager of Bureau of Geological Survey, and some others
  - ･Mining activities are open for any individuals and enterprises of foreign nationals as well as domestic ones
  - ･Mining rights shall include prospecting licenses, exclusive prospecting license, mining operation license, special mining operation license, special permit, special permit for coal, oil, natural gas, and nuclear resources
  - ･Miscellaneous

(Mining policy)

No information is available on environment management.

(Regulations for Mine Environment)

Mining Engineering Authority supervises environment management of operating mines. However, no information is available on environment management.

Table 3.23 Operating mines in Zimbabwe (1)

No	Name of Mines	Proprietor (ratio)	Location	Kind of ore	Mining Method	Mining Period	Amount of Production Products)		Environmental Issues	Safety issues
1	Ngezi		Great Dyke	Pt	?	? -	? t/y			
2	Unki		?	Pt, Ni	?	? -	1.86 Mt/y 80000 t/y 3000 t/y	ore Pt ore Ni metal		
3	Shabanie	African Associated Mines Ltd.	Zvishavane	Asb	?	? -	2.4 Mt/y			
4	Gaths	African Associated Mines Ltd.	Mashava	Asb	?	? -	1.4 Mt/y			
5	?	Local cooperatives	Southern Great Dyke	Cr	?	? -	0.34 Mt/y			
6	?	Local cooperatives	Northern Great Dyke	Cr	?	? -	0.23 Mt/y			
7	Inyala	Zimbabwe Alloys Ltd.	?	Cr	?	? -	60000 t/y			
8	Peak, Block, Ironton, Rhodesdale	Zimbabwe Mining and Smelting Co., Ltd .(Zimasco)	Shurugwi, Lalapanzi	Cr	?	? -	0.12 Mt/y			
9	Hwange	Hwange Colliery Company Ltd. [Government (37.07), Mesina Investments Ltd. (15.08), Mittal Steel African Investments (9.76), Others(38.09)]	Hwange	C	OP&UG	1903 -	2.0 Mt/y			
10	Sengwa	Sengwa Colliery Ltd.	Northeast of Kadoma	C	OP	1995 - 2008	5.0 Mt/y			
11	Chiredzi	Steelmakers Zimbabwe Ltd.	Southeast of Masvingo	C	?	? -	1.2 Mt/y			
12	Chiredzi	Tulicoal Ltd.	Southeast of Masvingo	C	?	? -	1.2 Mt/y			
13	Trojan, shangani	Bindura Nickel Corporation Ltd.	Bindura, Northeast of Bulawayo	Co	?	? -	800 t/y			

Table 3.23 Operating mines in Zimbabwe (2)

No	Name of Mines	Proprietor (ratio)	Location	Kind of ore	Mining Method	Mining Period	Amount of Production Products)		Environmental Issues	Safety issues
14	Mimosa	Mimosa Investments Ltd.[Aquarius Platinum Ltd., Impala Platinum Holdings Ltd. Zwishavane Community Share Ownership]	East of Zvishavane	Co	?	? -	86 t/y			
15	Unki	Unki Mines Ltd.	Southeast of Shurugwi	Co	?	? -	? Mt/y			
16	Ngezi	Zimplats Holdings Ltd.		Co	?	? -	? Mt/y			
17	Trojan, shangani	Bindura Nickel Corporation Ltd.	Bindura, Northeast of Bulawayo	Cu	?	? -	1600 t/y	metal		
18	Mimosa	Mimosa Investments Ltd.[Aquarius Platinum Ltd., Impala Platinum Holdings Ltd. Zwishavane Community Share Ownership]	East of Zvishavane	Cu	?	? -	3000 Mt/y	metal		
19	Unki	Unki Mines Ltd.	Southeast of Shurugwi	Cu	?	? -	1000 Mt/y	metal		
20	Ngezi	Zimplats Holdings Ltd.	?	Cu	?	? -	3000 Mt/y	metal		
21	Marange deposit	Anjin Investments Ltd. [joint venture of Anhui Foreign Economic Construction Group and Matt Bronze) Ltd.]	Chiadzwe	Dia	?	? -	? TC/y			
22	Murowa	Murowa Diamonds Ltd. [Rio Tinto plc and RioZim Ltd.]	Zvishavane	Dia	?	? -	367 TC/y			
23	River Ranch	River Ranch Ltd.	Beitbridge	Dia	?	? -	? TC/y			
24	Penhalonga	DTZ-OZGEO Ltd. [Joint venture of Development]	Northwest of Mutare	Au	?	? -	? kg/y			
25	Vubachikwe	Duration Gold Ltd.	Gwanda	Au	?	? -	? kg/y			
26	Athens	Duration Gold Ltd.	Mvuma	Au	?	? -	? kg/y			
27	Gaika	Duration Gold Ltd.	Kwe Kwe	Au	?	? -	? kg/y			

Table 3.23 Operating mines in Zimbabwe (3)

No	Name of Mines	Proprietor (ratio)	Location	Kind of ore	Mining Method	Mining Period	Amount of Production Products)	Environmental Issues	Safety issues
28	Sunace	Duration Gold Ltd.	North of Bulawayo	Au	?	? -	? kg/y		
29	Golden Quarry	Falcon Gold Zimbabwe Ltd.	North of Shurugwi	Au	?	? -	? kg/y		
30	Dalny Complex	Falcon Gold ZM Ltd.	Northwest of Chegutu	Au	?	? -	? kg/y		
31	Bell riverlea	Homestake Mining and Technical Services Ltd.	West of Kwe Kwe	Au	?	? -	? kg/y		
32	Chaka	Homestake Mining and Technical Services Ltd.	Kwe Kwe	Au	?	? -	? kg/y		
33	Monti Christo	Homestake Mining and Technical Services Ltd.	Northwest of Kwe Kwe	Au	?	? -	? kg/y		
34	Primrose	Homestake Mining and Technical Services Ltd.	Kwe Kwe	Au	?	? -	? kg/y		
35	How	Metallon Gold	Southwest of Bulawayo	Au	?	? -	? kg/y		
36	Shamva	Metallon Gold	Shamva	Au	?	? -	? kg/y		
37	Freda rebecca	Mwana Africa PLC	Bindura	Au	?	?	2000 kg/y		
38	Turk-Angelus	New Dawn Mining Corp.	Northeast of Bulawayo	Au	?	?	500 kg/y		
39	Old nic	New Dawn Mining Corp.	Bulawayo	Au	?	?	100 kg/y		
40	Renco	RioZim Ltd.	South-southeast of Masvingo	Au	?	?	1000 kg/y		
41	Ripple Creek	NewZim Minerals Private Ltd. [Essar Africa Holdings Ltd.(80), and Government, (20)]	Redcliff	Fe	?	?	0.6 kt/y		
42	Bikita	Bindura Nickel Corporation Ltd. (Mwana Africa PLC)	East of Masvingo	Li	?	?	0.033 kt/y		
43	Trojan, Shangani	Bindura Nickel Corporation Ltd.	Northeast of Bulawayo	Ni	?	?	0.08 kt/y		

Table 3.23 Operating mines in Zimbabwe (4)

No	Name of Mines	Proprietor (ratio)	Location	Kind of ore	Mining Method	Mining Period	Amount of Production Products)		Environmental Issues	Safety issues
44	Mimosa	Mimosa Investments Ltd.[Aquarius Platinum Ltd., Impala Platinum Holdings Ltd. Zwishavane Community Share Ownership]	East of Zvishavane	Ni	?	?	3000 t/y	metal		
45	Unki	Unki Mines Ltd.	Southeast of Shurugwi	Ni	?	?	1000 t/y	metal		
46	Ngezi,Ngwarati,Rukodzi,Bimba	Zimplats Holdings Ltd. (Impala Platinum Holdings Ltd.)	?	Ni	?	?	4000 t/y	metal		
47	Dorowa,	Dorowa Minerals Ltd.	West of Mutare	P	?	?	0.155 Mt/y			
48	Ngezi, Ngwarati, Rukodzi, Bimha	Zimplats Holdings Ltd.	?	PGM	?	?	2.2 Mt/y			
49	Unki	Unki Mines Ltd.	Southeast of Shurugwi	PGM	?	?	1.44 Mt/y			
50	Iron Duke	Iron Duke Pyrites (Chemplex Corporation Ltd.)	?	Py	?	?	? Mt/y			
51	Shawa	Shawa Vermiculite Ltd.	Dorowa	Vm	?	?	0.039 Mt/y			
52	Dinidza	Dinidza Vermiculite Mining Co. Ltd.	Dorowa	Vm	?	? -	0.01 Mt/y			

Table 3.24 Operating refineries in Zimbabwe

No	Name of Smelter	Proprietor (ratio)	Location	Kind of ore	Smelting Method	Smelting Period	Amount of Production Products)		Environmental Issues	Safety issues
1	Bindura	BSR Ltd. [Bindura Nickel Corporation Ltd. (100]	Bindara	Ni	Rf	? -	0.011 Mt/y			
2	Eiffle Flats	Empress Nickel Refinery (RioZim Ltd.)	Kadoma	Ni	Rf	? -	9,000 t/y			
3	Eiffle Flats Ref.	Empress Nickel Refinery (RioZim Ltd.)	Kadoma	Cu	Rf	? -	6,000 t/y			
4	Blast	NewZim Steel Private Ltd.[Essar Africa Holdings Ltd.(53.4) Government (35.6)]	Gweru	Fe	Sm	? -	0.072 Mt/y	crude ore		
5	Electric	Steelmakers Zimbabwe Ltd. (Steelmakers Ltd.)	Redcliff	Fe	Rf	? -	0.015 Mt/y	rolled steel		
6	Rolling mill	Steelmakers Zimbabwe Ltd. (Steelmakers Ltd.)	Redcliff	Fe	Rf	?	0.036 Mt/y	rolled steel		
7	Selous	Zimplats Holdings Ltd. (Impala Platinum Holdings Ltd.)	?	PGM	Con	?	2.18 Mt/y			
8	Mimosa	Mimosa Investments Ltd. (Aquarius Platinum Ltd., and Impala Platinum Holdings Ltd.)	East of Zvishavane	PGM	Con	?	1.9 Mt/y			
9	Selous	Zimplats Holdings Ltd. (Impala Platinum Holdings Ltd.)	?	PGM	Con	?	0.072 Mt/y			

(4) Role of Directorate of Geological Survey

The Directorate of Geological Survey is under the control of MMMD and is assigned to conduct geological survey, exploration of ore deposits, and construction of database for geology and ore deposits. The Directorate of Geological Survey reports to MMMD with recommendations after reviewing each of the exploration license applications. The Directorate of Geological Survey has no concerns with status quo of the operating mines and their mining-induced damages.

(5) Chemical analyses

MMMD has its own laboratories for chemical analyses of air, water, and soil. There are state-run laboratories under the administration of Environment Management Agency also. In addition to this, there are 5 to 6 laboratories attached to private mining companies. Each of these is usually specialized in its own specific element, for example, gold or base metal for analyses as a part of mining business activities hence they lack in comprehensive analytical capability of multiple elements and maintaining accuracy in environmental analyses.

(6) International cooperation

No information is available on international cooperation as far as MMMD is concerned.

3.5.4 Environmental policy of MEW and its status quo

Ministry of Environment, Water and Climate (MEW) is largely responsible for all environmental issues. They also form an umbrella organization consisting of National Environment Council (NEC), Environment Management Board (EMB), and Environment Management Authority (EMA). This organizational structure came about after an administrative reform encompassing abolition and consolidation of governmental departments in October. In fact, MEW was born to go independent of the former Ministry of Environment and Natural Resources however, it is still in a transitional mess regarding the personnel affairs and it also has separated offices in three different places. Figure 3.28 shows the umbrella organization structure of MEW.

In summary, MEW is in a position of "policy making", EMA is "execution of policy", NEC is "supporting MEW", and EMB is " supervising EMA". Main roles of MEW are as follows:

- To regulate environment management, promote environmental protection, control, adjust, and observe environmental pollution.
- To regulate activities in relation to environmental impact of all the governmental departments and any other institutions.
- To submit a report on status quo of environment every 5 years to the Diet
- To monitor utilization of environment and natural resources and their impact against environment.

- To promote public awareness for environmental protection through enlightenment and education.
- To secure enough funds borne by responsible parties and institutions for environmental damages to restore original environmental conditions.
- To make plans of environment management policies and have them executed appropriately
- To recommend that government take part in international / regional treaties / conventions on environmental issues while making sure of domestic legislation.

EMA is the organization for implementation and management of environmental policies in general and made up of Environment Protection Division, Environment Management Division, Waste Management Division, Administration Division, accompanying laboratory, and some others. They carry out assignments in relation to environment such as environment management (planning, practice, setting up guidelines), prescription of standard values for environmental regulations, management of radioactive waste (collection, processing, and recycling), monitoring, inspection and audit, EIA, protection of ecosystem, chemical assay and analysis, etc. The information above mainly came from Director of Environment Services Authority of MEW and General Manager of Environment Services Division of EMA (Photo 3.23).

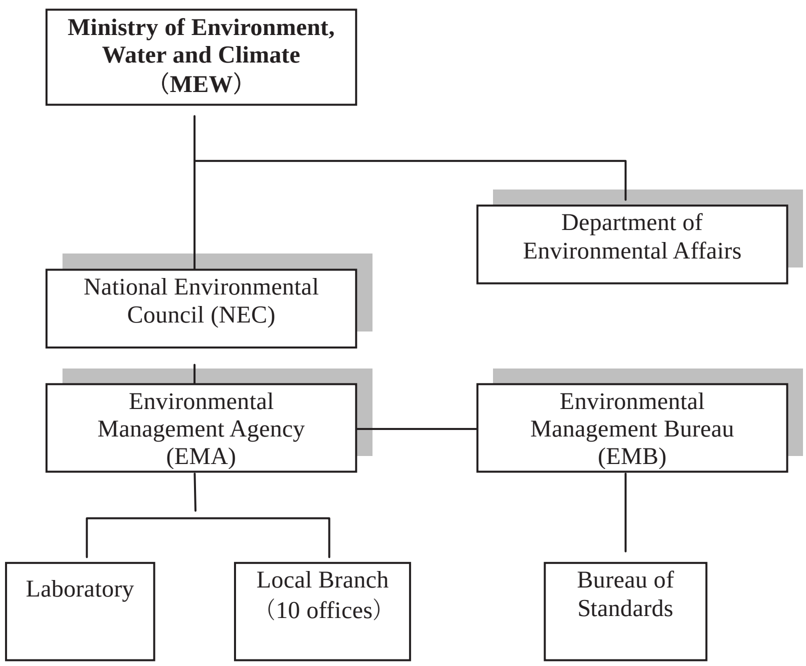


Figure 3.28 Organization of MEW

Photo 3.23 Conference at EIA Authority of MEW

(2) Environment-related laws and regulations

a. Environment related laws and regulations

- Environment Management Act (2002): The basic law on environment including environment management, EIA, waste management, others.
- EIA policy (1997)
- Outline of National Environment (2003)
- Water Act (2003)
- Forest Act (1949)
- National Park and Wildlife Protection Act (1975)
- Common Land and Forest Production Act (1988): local government law
- Animal Hunting Management Act (1974)
- Agrichemicals and Illness Act (1959)
- Water Quality Standards
- Ground Water Quality Standards
- Noise Standards
- Potable Water Quality Standards

(No regulations against soil contamination.)

Following are interpretation and actual practices of environment-related regulations, particularly for EIA in Zimbabwe:

- Both MEW and EMA are involved with EIA for all the mine development projects. The EIA report is supposed to go first to Ministry of Environment, Water and Climate. Then, specialized officers in charge of environment, who are of Mine Authority of Ministry of Geology and Mines, will review the report with some comments which will be submitted to EMA. "Environment permission" is finally issued by MEW after the comprehensive review and approval of EMA.

- A similar procedure is applied to EIA for prospecting projects. For larger scale exploration , one which may effect a greater influence on the environment, a full scale EIA is a requirement
- Procedure of EIA starts with preliminary "scoping" followed by confirmation of "terms of reference" (TOR), completion and submittal of EIA and EMP, review of MEW and EMA for 60 days, approval of EIA with some conditions such as monitoring and environment management, starting of a business with monitoring for report, and ended with inspection and audit by EMA.
- Hearing of opinions covers limited local governments in and nearby the project site. Otherwise public hearing is held for a large scale project.
- "Environment Management Law" specifies several environment standards as follows:
  - Air quality standards
  - Water quality standards
  - Waste standards
  - Noise and vibration standards, and others

b. Procedure for Environment Impact Assessment (EIA)

Figure 3.29 shows the procedure of EIA in Zimbabwe. As previously indicated, Ministry of Environment, Water and Climate, practically EMA as the executing body performs a major role for EIA of all the mine developments. The EIA report is supposed to go first to EMA. Then, specialized officers in charge of environment, who are of Mine Authority of Ministry of Geology and Mines, will review the report with some comments which will be submitted to EMA. "Environment permission" is finally issued by MEW after the comprehensive review and approval of EMA.

c. Laboratory for chemical analyses

There is a laboratory for chemical analyses under the administration of EMA. The laboratory is relatively well organized and equipped to accommodate the requests of analyses of area-wise monitoring data as well as the request from outside of ordinary chemical analyses. The monitoring is not to directly measure mining-induced damages on the spot which can be, however, estimated based on monitoring results of surrounding polluted areas. Unfortunately, the laboratory cannot keep pace with increasing data to be compiled into a database because of a transitional mess due to reformation of governmental organization.

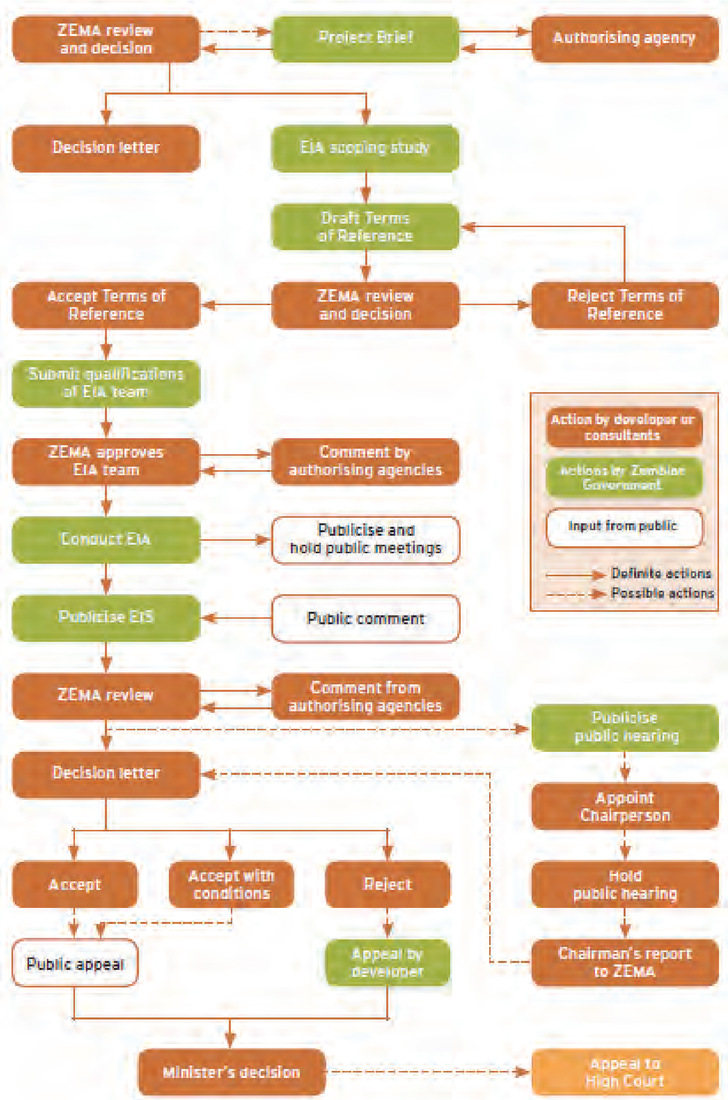


Figure 3.29　Procedure for EIA in Zimbabwe

(3)　Mine environment

No information on mine environment was given by MMMD but the laboratory of EMA disclosed monitoring results as follows:

- Potential areas threatened with mining-induced damages are indicated by MEW and EMA based on the monitoring results : There are 4 such areas as 1) Mashoraland　Central, northwest of Harare, 2) Mashoraland West, southwest of Harare, 3) Midland, central part of Zimbabwe, and 4) Miat South, southwest of Zimbabwe.　All of these areas are located either in "Green Stone Belt" or along "Great Dykes".
- The names of points of the damages were not specified because they weren't yet reported to the MMMD.　There is, however, a publicly known academic paper on mining-induced damages by discharge from an Au mine.　Several other mines may have also the same kind of problem.

3.5.5 State of Mine Pollution and the Potential

(1) Mine Environment

No information on mine environment was given by MMMD but the laboratory of EMA disclosed monitoring results as follows:

- Potential areas threatened with mining-induced damages are indicated by MEW and EMA based on the monitoring results : There are 4 such areas as 1) Mashoraland Central, northwest of Harare, 2) Mashoraland West, southwest of Harare, 3) Midland, central part of Zimbabwe, and 4) Miat South, southwest of Zimbabwe. All of these areas are located either in "Green Stone Belt" or along "Great Dykes".
- The names of points of the damages were not specified because of no opportunity of hearing from MMMD. There is, however, a publicly known academic paper on mining-induced damages by discharge from an Au mine. Several other mines may have also the same kind of problem.

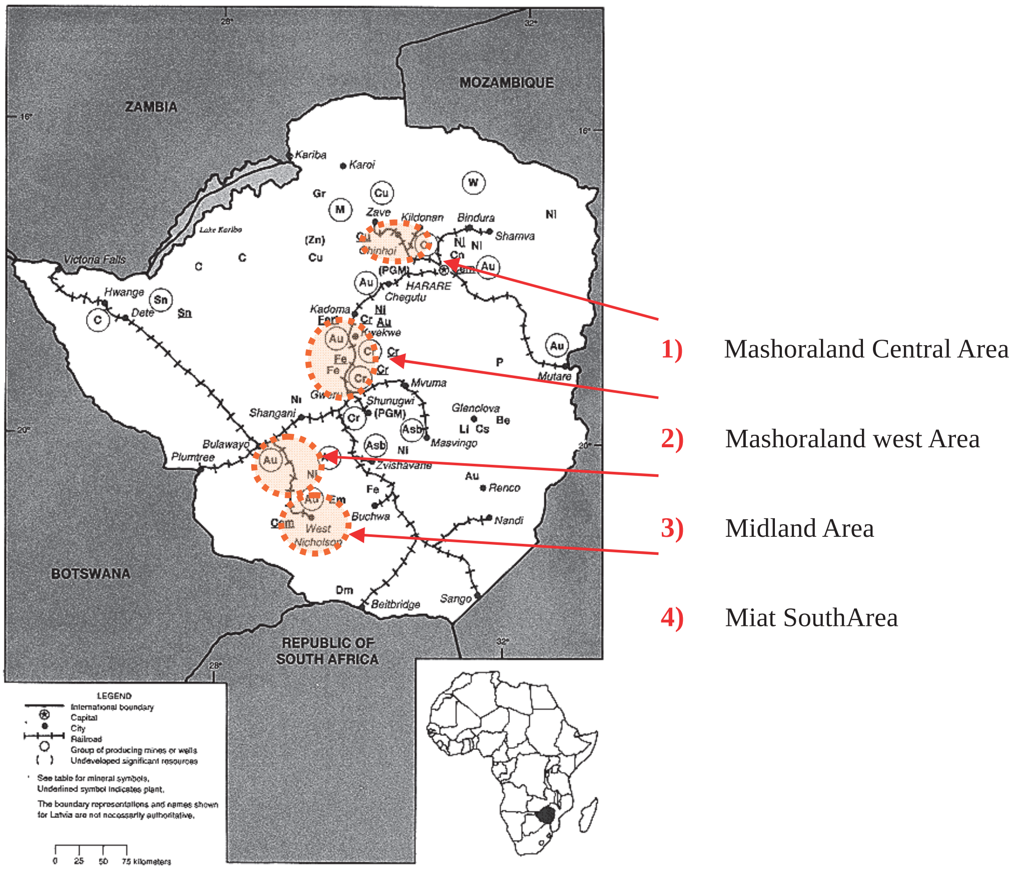


Figure 3.30 Location of Potential Areas of Mining-Induced Damages

(2) Site Investigation

Site investigation was carried out at Shackleton Mine in the Chinhoyi District together with the Manager of Chinhoyi Branch of MMMD, Branch Manager of ZMDC, and two staff of ZMDC.

(Overview of the Ore Deposit)

The Chinhoyi District is located about 120 km northwest from Harare (Capital of Zimbabwe), and the Shackleton Mine is situated in the central part of the district (Figure 3.31).

The Shackleton Mine is copper ore deposit occurred in the meta-arkose sandstone and meta-basic volcanic rocks of the Middle Pre-Cambrian and is formed high grade Cu deposit composed of chalcopyrite, bonite and chalcocite as main ore components.

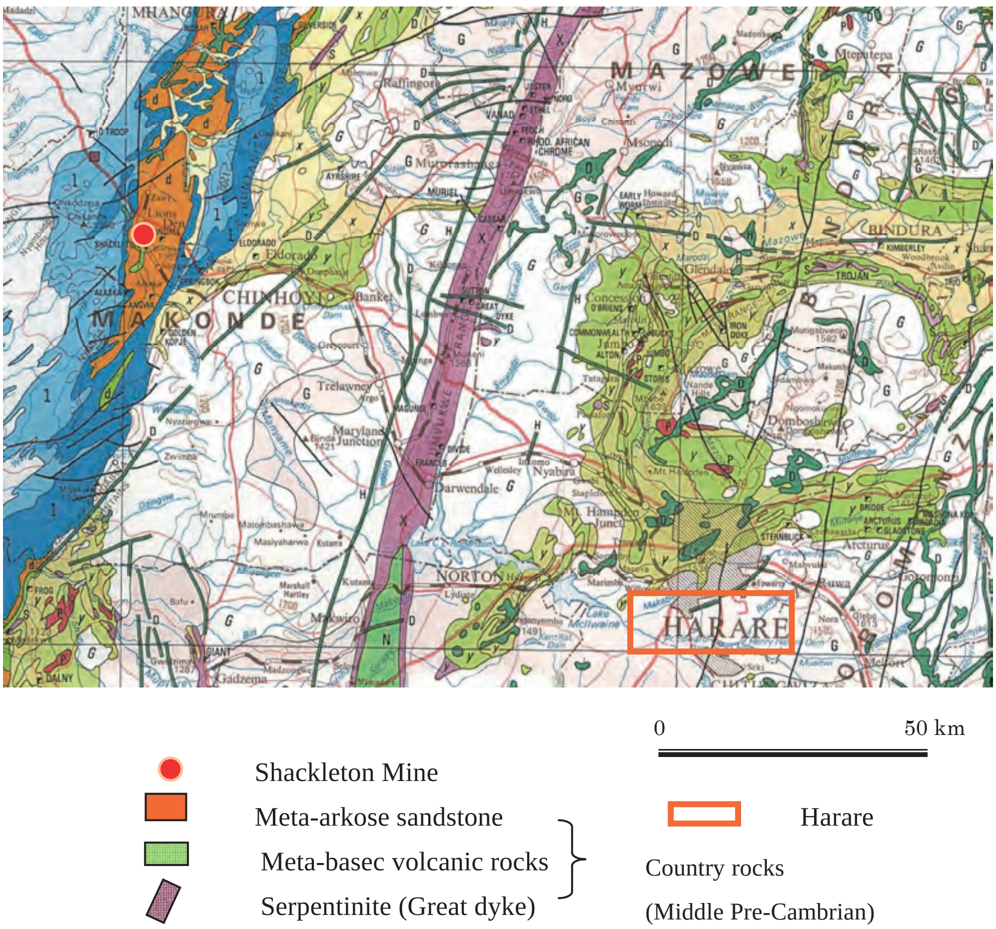


Figure 3.31 Location and Geology of Shackleton Mine

This mine consist of concentrator and semelter – refinery as associated facilities and closed in 2001. However, Cu ore is likely to be still remained, there is possibility of re-development of mine.

(Mine Facilities)

The Shackleton Mine was underground mining and main mine facilities in the site are vertical shaft, waste dump area and concentrator (Photograph 3.24 to 3.28).

Tailings dam is located about 2 km from mining site, and closed Smelter and Refinary are adjacent the mining site (Photograph 3.29 to 3.31). And the railway was laid down to the mine for the transportation of the products and materials, etc.

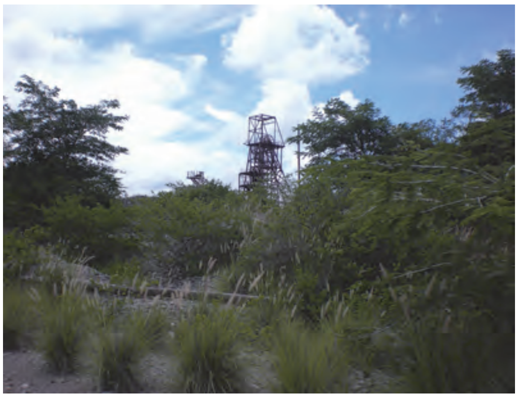


Photo 3.24 State of shaft and mining area

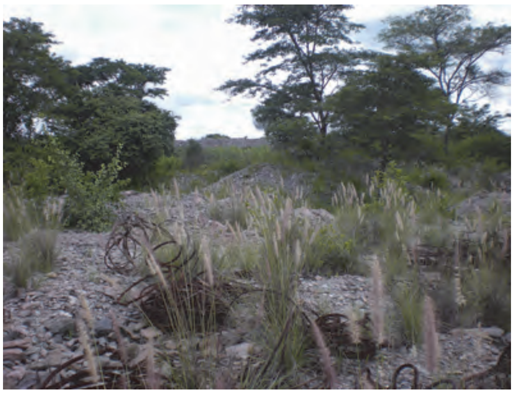


Photo 3.25 Waste rock dump (Vegetation covered already.)

Photo 3.26 Primary crushing plant

Photo 3.27 Concentrator and thickener

Photo 3.28 Stockpile of concentrate
(Cu concentrates are remaining)

Photo 3.29 Slag dump
(Vegetation are covered the area.)

Photo 3.30 Top of slag dump

Photo 3.31　Smelter (left) and refinery (right)
: slag dump locates in left side of photograph.

(Result of the site investigation)

- Mining site: Underground mining site is situated several 100 m below ground, present drifts may be filled by groundwater, because the mine water is not pumped up from vertical shaft. Then, the vertical shaft is also closed. Therefore, mined site is thought to be reduction circumstance, and the acidic water is likely not to be occurred. In addition, the hanging wall side of the ore deposit consists of carbonate rocks including dolomite, etc., thus the circumstance is easy to be neutralized.
- Consentrator: The consentrator is still remained primary crusher, ball-mill, flotation, etc., and these equipments are partly maintenanced, thus contaminated condition is not recognized in the site. And the residual water in the facilities shows neutral condition (pH).
- Waste dump area: Waste rocks mainly consist of meta-basic volcanic rocks, meta-sediments, dolomite and quartzite. The waste does not contain much sulphide ore. In addition, the pyrite is relatively low content in the ore, and carbonate rocks as keeping under control of acidification, contain in the waste rocks.
- Tailings dam: Tailings mainly consists of quartz, sulphide ores, such as pyrite, are not contained in the tailings. Therefore, the potential of acidification is likely to be very low. And then, the slope of the tailings dam is covered by vegetation.
- Smelter, Refinary and slag dump area: Although the site could not found inside, the site is likely to be keeped by security and maintenance.

The Shackleton Mine is though to be relatively low potential of occurrence of mine pollution.

3.5.6 Mine safety

Information obtained is as follows:

- Mine safety is specified in Mining Law.
- There is a decent number of casualties through mining activities, being raised as an issue on mine safety.
- Statistics of mine accidents and casualties are as follows:

Year	No. of accidents	No. of casualties (dead)
2010	36	40
2011	30	37

- Statistics of cause of accidents and corresponding number is as follows

1) Rock falling:	12
2) Falling down through a shaft:	11
3) Falling of wall in open-cut mining:	4
4) Outburst of gas:	3
5) Tumbling down of rocks:	2
6) Tumbling:	1
7) Falling down:	1

8) Machine operation: 1
9) Electricity-related: 1
10) Blasting: 1
11) Others: 3

- COM is providing a training course of mine safety for miners and publicizes an annual statistics report on mine accidents and casualties.

3.5.7 Present State of Human resources development and request for Technical Training

(1) Human resources development

Neither MEW nor EMA is earnest in human resources development for their own personnel.

(2) Request for technical training by Japan

Neither MEW nor EMA has its in-house training programs for their own personnel.

- There has been no support of foreign countries in an area of human resources development except for Japan: JICA has accepted a small number of government personnel since 2000 in training courses for waste management, chemical analyses, environment management, etc.

The following is the current request by the Directorate of Geology and Directorate of Mines of Ministry of Geology and Mines for support from Japan in human resources development:

- Long term training: 1 to 2 years including a master course
- Medium term training: 6 months to 1 year
- Short term training: 1 to 3 weeks

(Directorate of Mining Development of MMMD)
There was no opportunity to receive such requests from the MMMD.

(Directorate of Environment Services of MEW)
Support has been sought for:

- Environment policy: 4 personnel (1 for long term and 3 for short one)
- Environment planning: 4 personnel (1 for long term and 3 for short one)
- Environment management: 4 personnel (2 for long term and 2 for short one)

(EMA)
They would like training for up to 32 personnel (12 for long term and 20 for short term) in Japan covering areas of environment policy and management including mine environment assessment,

environment management and planning, environment monitoring, environment audit, countermeasures for mining-induced damages.

3.6 Mozambique

3.6.1 Outline of Mozambique

(1) Current State of National Affairs and Economic Indicator in Mozambique

The current state of national affairs and the economic indicator of Mozambique are:

- Area : 799,000 km^2 (Approximately 2.1 times of Japan, refer to Figure 3.32).
- Population : 23,920,000 persons (in 2011, WB).
- Capital City : Maputo (Population: Approximately 1,970,000 persons in 2012, EIU).
- Races : 43, mostly Makua-Lomuwe people, etc.
- Languages : Portuguese (Official language).
- Major Industries : (Agricultural and Fisheries Industry) Corn, sugar, cashew nut, tobacco, timber, shrimp, etc.
  (Industrial Products) Aluminum, coal, natural gas, etc.
- GNI (Gross National Income): US$ 12,800 million (in 2011: WB).
- GNI per person : US$ 510 (in 2012: WB).
- Rate of Economic Growth: 7.0% (in 2012: WB).
- Price Increase Rate: 10.35% (in 2011: WB).
- Total Amount of Trade: Export: US$ 4,160 million.
  Import: US$ 661 million (in 2012, WB).
- Major Export Goods: Aluminum, natural gas, tobacco, electricity, shrimp, timber, sugar, etc.
- Major Trading Partner (in 2012: estimated by CIA):
  - Export : Holland (48.9 %), South Africa (22.2%), Zimbabwe (3.6 %), Malawi (3.6 %).
  - Import : South Africa (37.0 %), China (20.0 %), Holland (9.8%), UAE (4.6 %).
- Currency : Metical (MZN).
- Exchange Rate : US$ 1 ＝ Approximately 30 MZN (in November, 2013).
- General Situation of Economy:

  The economy of Mozambique has been active so far, with the economical growth reaching 6% per every year and investments from South Africa are increasing. The investments from South Africa are construction project for an aluminum smelting plant, Maputo corridor project and Beira corridor project. These are based on the consolidation of peace after the civil war in the late 90s.

  Mozambique economy has received blows by flooding disasters in 2000 and 2001. However, the economy headed for recovery from late 2001, with infrastructure repair projects for rehabilitation launched and direct investments by overseas enterprises continuing strongly. Based on this, the growth has reached 7 to 8% per year so far.

- Major Donor Country (in 2011, OECD/DAC): USA, Portugal, UK, Canada, EU, etc.
- Records of International Cooperation and Assistance by Japan:

(1) Onerous Financial Assistance (~2011, base on EN) : ¥ 9,260,000,000 (Japanese Yen)
(2) Gratuitous Financial Assistance (~2011, base on EN) : ¥ 88,432,000,000
(3) Technical Cooperation (~2011, base on JICA) : ¥ 13,127,000,000

- Local Administrative District: 1 city and 10 states (Refer to Figure 8.1)

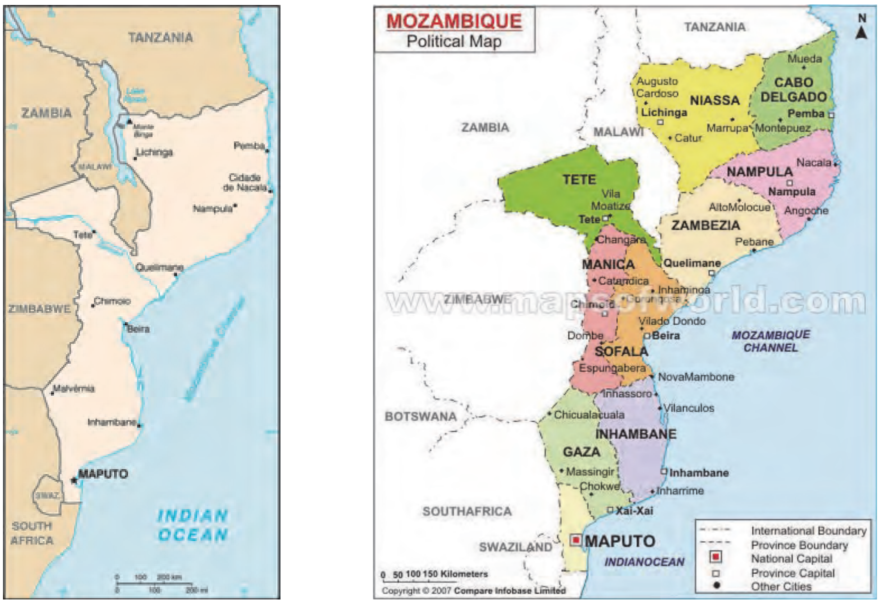
(2) State of Nature

a. Geographical Features

Republic of Mozambique is located in the eastern part of the African Continent sharing the country borders with Tanzania, Malawi, Zimbabwe and South Africa. The country's shores reach the Indian Ocean with Madagascar in the east (Figure 3.32). The capital city is Maputo.

The country's landscape consists of highland and lowland. In the north of Zambezi River, highlands are mainly formed in Nyasa, Namuli, Angonia, Tete and Makonde with dense forest. Lowlands are formed in the south of Zambezi River.

There are five main rivers in Mozambique and Zambezi River as the largest river, situated in the central part of the country. Lake Nyasa, Chiuta and Chilwa are located along the rivers.



(Google Image)

Figure 3.32 Country of Mozambique and Administrative Division

b. Geological Features and Mineral Deposits

Geology of Mozambique is divided into Precambrian and Phanerozoic stratums. Among these, the stratums of Precambrian are distributed in the northern and northwestern parts of the country and the stratums consists of igneous and metamorphic rocks of Archean to early Proterozoic. Barue complex which consists of granites, gneiss and migmatite, corresponds to these stratums as well. Phanerozoic stratums are distributed in the south of Zambezi valley and northeastern parts of the coastal area, and are comprised of volcanic rocks of Karoo System, Jurassic, Cretaceous, Tertiary and Quaternary (Figure 3.33).

Gold, base metals, tantalum bearing pegmatite and tin are observed in the Precambrian stratums. Carbonatite complexes and their mineralization are also observed in the Precambrian stratums as host rocks. Coal, heavy sand, limestone, bentonite and diatom as industrial materials are included in relatively young stratums (Figure 3.34).

Gold is mostly produced in Archean Greenstone Belt and alluvium where large-scale banded iron formations exist in the area. Tantalum, niobium, rare earth minerals and gems as strategic minerals are observed in the pegmatite distribution of the Greenstone Belt. On the other hand, heavy sand, graphite, fluorite, apatite, bauxite, aggregates, clay, sands, refractory minerals, limestone, coal and natural gas are produced in flat areas.

As observed above, there are prenty metallic and nonmetallic minerals in Mozambique. However, these reserves have not been identified as accurate assessment.

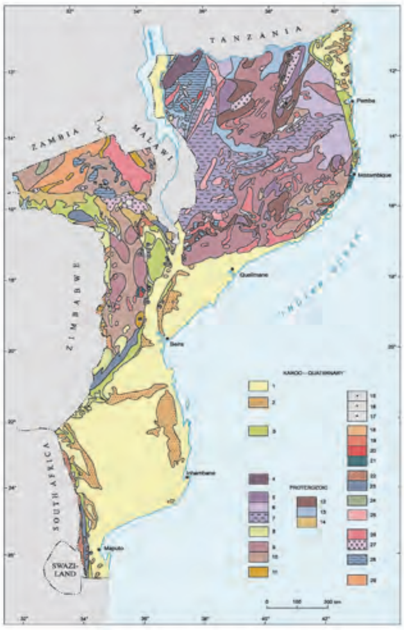
Potential minerals for prospecting are as follows:

Deposit in Precambrian stratum: niobium, tantalum, rare earth minerals, gold, fluorite, graphite, tin, feldspar, kaolinite, copper, asbestos, iron, garnet, carbonatite and pegmatite related minerals (apatite, precious stones and others) and decorative stones (marble, granites and so on).

Deposit in Phanerozoic stratum: clay, sands, refractory minerals, limestone, diatom, bentonite, heavy sand, coal, natural gas and apatite.

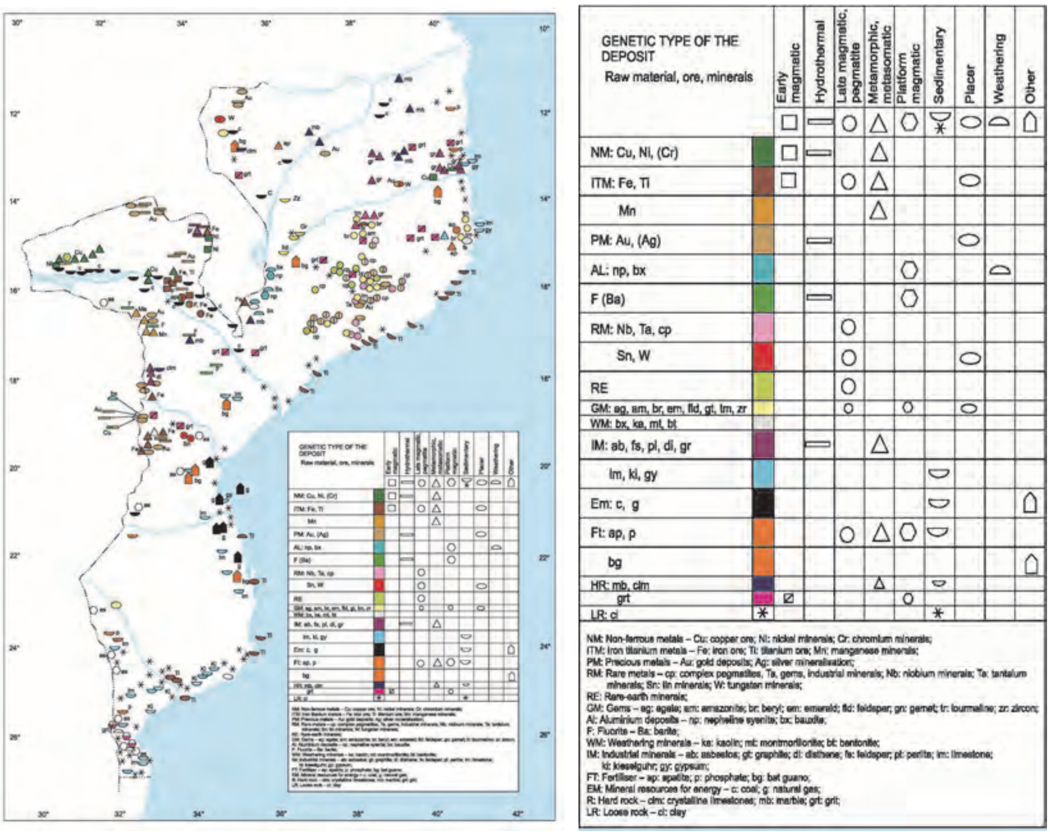
c. Climate

Mozambique has tropical rainforest and savanna climates. The average temperature in the winter season hardly reaches below 20°C in southern parts of the country such as Maputo with the weather getting a little more bearable during May to September.



(JOGMEC, 2012)

Figure 3.33 Geology of Mozambique



(JOGMEC, 2012)

Figure 3.34 Distribution of Ore Deposit of Mozambique

3.6.2 The First Site Investigation

(1) Time Schedule on Site Investigation

The First Site Investigation in Malawi was carried out for five days from December 2 to December 6, 2013. The time schedule on the first field investigation carried out is tabulated in Table 3.25.

Table 3.25 Time Schedule on First Site Investigation in Mozambique

No	Month/ Day	Time	Place	Item of Work	Persons met
1	Dec./1 (Sun)	-	Johannesburg (South Africa) - Maputo (Mozambique)	Travelling.	-
2	Dec./2 (Mon)	 9:00 - 11:00 - 13:00 -	Maputo: JICA Office Ministry of Mineral Resources	 Courtesy and meeting on investigation. Courtesy and discussion for investigation. Arrangement of information and preparation of investigation.	 Representative and other related staffs Permanent Secretary and related engineers of the Ministry
3	Dec./3 (Tue)	8:30 - 13:00 -	Maputo: Avenida Hotel	Seminar. Arrangement of meetings.	National Directorate of Mines, National Directorate of Geology and National Directorate of EIA Attendees: 13 persons from Mozambique
4	Dec./4 (Wed)	9:00 - 13:30 - 16:30 -	Maputo: Environment Department , National Directorate of Mines Directorate of Geology	Arrangement for meeting. Interview, discussion, obtained information. Arrangement for meeting.	General Manager Deputy Director
5	Dec./5 (Thu)	8:30 - 13:30 - 15:00 -	Maputo: - National Directorate of EIA Environment Department , National Directorate of Mines	Arrangement for meeting and information. Interview, discussion, obtained information, receipt of the questionnaire, etc. Interview, discussion, obtained information, receipt of the questionnaire, etc.	Environmental Inspector General Manager and engineers
6	Dec./6 (Fri)	8:30 - 15:00 - 16:30 -	Maputo: - JICA Office Embassy of Japan in Mozambique	Arrangement of information. Report on outlines of investigation. Report on outlines of investigation.	- Deputy Representative and other staffs First Secretary
7	Dec./7 (Sat)		Maputo (Mozambique) - Johannesburg (South Africa) - Dubai (UAE)	Travelling.	-

(2) Governmental Organizations Concerned

The organizations and offices where the delegation visited to and the governmental organization, department, division, etc. related to the field investigation are as follows:

Place where the Delegation visited to:

- Embassy of Japan in Mozambique
- JICA Mozambique Office

Relating Governmental Organization, Directorate, Department, etc.:

- Ministry of Mineral Resources: National Directorate of Mines
- Ministry of Mineral Resources: Directorate of Planning and Development
- Ministry of Mineral Resources: National Directorate of Geology
- Ministry of Mineral Resources: Environment Department, National Directorate of Mines
- Ministry of Environment: National Directorate of EIA

(3) Holding of Seminar

Seminar in Mozambique was held in a conference hall of Avenida Hotel on 3rd December. The participants in the Seminar reached thirteen consisting of seven from Ministry of Mineral Resources and six from Ministry of Environment (Photo 3.32 and 3.33, Table 3.26). This seminar received local TV (TVM) coverage.

To begin the seminar, Ms.Morita, Senior Representative of Mozambique Office, greeted and spoke about the study which is planned to assist sustainable mining to the mining sector of Mozambique from JICA. After the speech, the study team made their presentations, and Ms. Marta Nicole Mucavel (lawyer for Ministry of Mineral Resources) and Ms. Rosana Francisco (agricultural engineer of National Directorate of EIA) explained about keys aspects of the mining related law and mechanism of the EIA in the country. After these, study team explained about Japanese experiences to overcome the mine pollutions.

The presentations attracted interest from participants. It is believed that the seminar was productive due to the involvement of persons in charge of mining.

Photo 3.32 Seminar at Avenida Hotel
(Mozambique side also provided presentations.)

Photo 3.33 Seminar at Avenida Hotel
(13 participants were joined.)

List of attendees to the seminar is presented in Table 3.26.

Table 3.26 List of Attendants to Seminar

No	Name	Organization / Division	Position
1	Suzete M. C. Taimo	Environment Department, Ministry of Mineral Resources	General Manager
2	Marta Nicole Mucavel	Ministry of Mineral Resources	Lawyer
3	Anselmo C. Gaspar	National Directorate of EIA, Ministry of Environment	Environmentalist
4	Cristina Matsimbe	National Directorate of EIA, Ministry of Environment	Technician
5	Rosana Francisco	National Directorate of EIA, Ministry of Environment	Technician
6	Mauricio Matega	Ministry of Mineral Resources	Technician
7	Gabriel Batista	National Directorate of Geology, Ministry of Mineral Resources	Geologist
8	Helena Vaz	National Directorate of Geology, Ministry of Mineral Resources	Geologist
9	Corneilio De Jesus	National Directorate of Geology, Ministry of Mineral Resources	Geophysist
10	Laura Nhantumbo Hantenbi	Ministry of Environment	Technician
11	Filix Paipe	WUA , Ministry of Environment	Technician
12	Custodio Mabio	Dept GA , Ministry of Environment	Technician
13	Hilario Mavie	National Directorate of Geology, Ministry of Mineral Resources	Geologist
14	Chiharu Morita	JICA Mozambique Office	Senior Representative
15	Issei Aoki	JICA Mozambique Office	Assistant Representative
16	Antonio Mauvilu	JICA Mozambique Office	Staff
17	Yoshimitsu Negishi	JICA Study Team	JICA Study Team
18	Hirohisa Kobayashi	JICA Study Team	JICA Study Team

(Explanatory Leaflet, etc.)

The seminar was carried out using the projector at the conference room. Presentation materials used in the seminar are three files, namely:

1) Investigation in Africa - Explanation on Background of JICA: Activities of JICA, and
2) Investigation in Africa - Explanation on Mine Environment and Safety, Environmental pollution caused by mining and its countermeasures, etc. in Japan, and
3) Investigation in Africa - Explanation on Japanese Experiences for Sustainable Mining in

respect to Mine Environment and Safety.

(Questions and Answers)

The questions and answers session included:

- Scheme of assistance and the actual achievements by JICA
- Methods of management for abandoned mines in Japan
- Methods to reduce mine pollution
- Criterion to select investigation sites for 2nd study in countries
- Concern about use of mercury with placer gold mining

3.6.3 Policy and State on Mineral Industries

(1) Directorate/Department and Organization in Charge

National Directorate of Mines, Ministry of Mineral Resources, has been conducting a broad range of tasks such as approval and license for exploration and mining, audit of mining and mine safety, monitoring of mine environment, approval and license for EIA and economic analysis to build mineral resources policy (Photo 3.34 and 3.35). Among these, the Environmental Department is in charge of mine environment and General Inspection of Mines is in charge of mine safety (Figure 3.35). These departments are collaboratively conducting their environmental and safety works together with Ministry of Environment, Ministry of Labor and Ministry of Health. However, the directorate is under review and the organization will be revised at an early date.

Photo 3.34 Courtesy call to Ministry of Mineral Resources (Interview with the permanent Secretary)

Photo 3.35 Interview with Manager for Environment Department, National Directorate of Mines

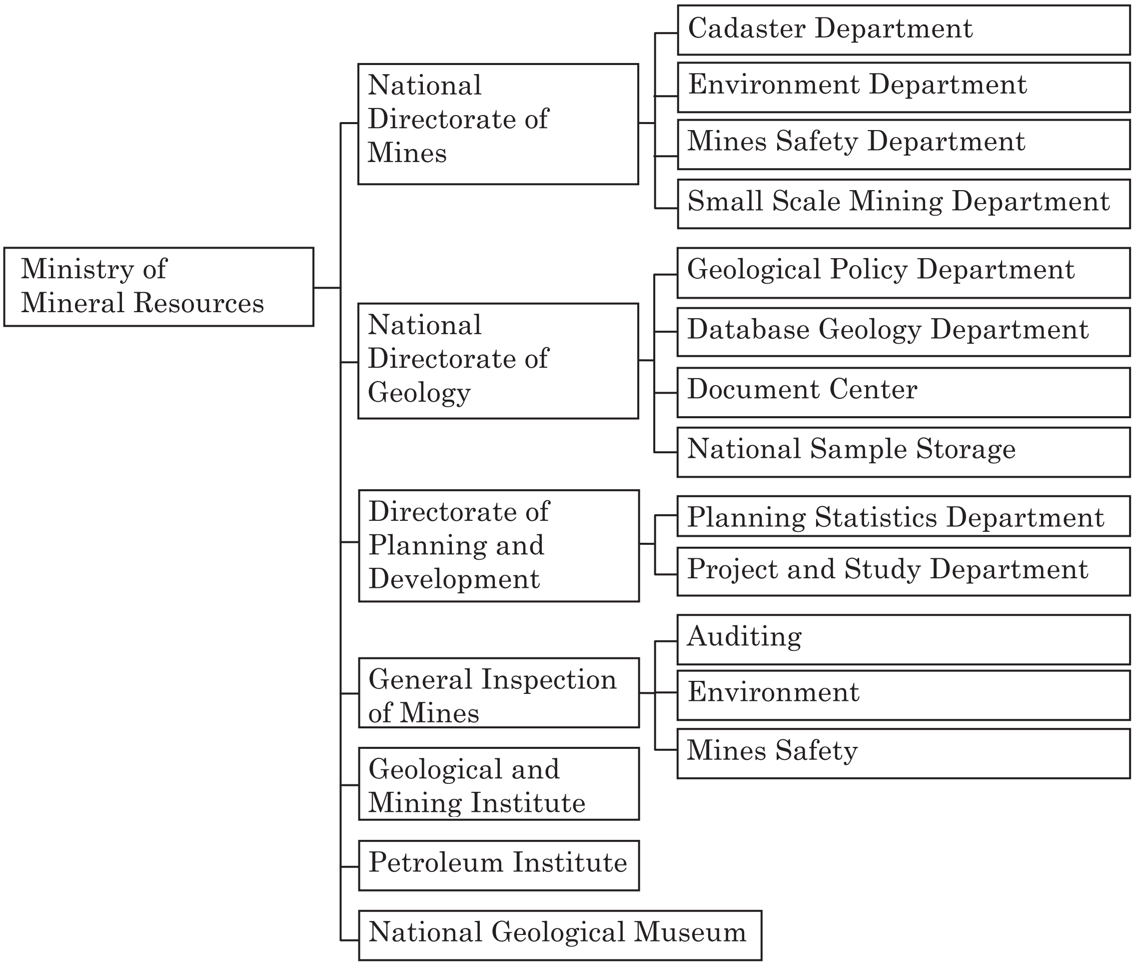


Figure 3.35 Present Organization Chart of the Ministry of Mineral Resources

(2) Laws, Acts and Regulations relating to Mining Industries

Related laws and regulations for mining in Mozambique are the Mining Law (established in 2002), the Environmental Regulations for Mining activities (established in 2004) and the Regulations Concerning Mining Operation Safety (established in 2006). Guidelines and procedures in respect to these laws have not been created so far. Related departments are revising these laws and regulations and the revised new mining law will be established at the immediate future.

Related laws and regulations of the mine environment in Mozambique are the Environmental Law (established in 1997 and revised in 2004) and the Environmental Quality and Effluent Emission Norms (established in 2004). Guidelines and procedures in respect to these laws and procedures have not created so far as well.

In related environmental regulation, government has been using original standards for discharged water and ground water.

(3) Policy for Mining Industries

Government is recognizing mineral resources in the country as a driving force of economic growth of Mozambique. Coal mine developments are activate at the moment and the government is counting that the degree of contribution to the GDP by coal would be scaled up 3% to 7% in 2015. In line with this, revised mining law and regulation were established in 2002 and 2003, which government aimed for to coordinate both the development acceleration of mineral resources and economic growth. Additionally, government included the components required for the development acceleration. The components consist of to create a basis of regal environment, to improve mining related infrastructure, to increase value-added mineral resources products and to promote partnerships between domestic private sector and government mining sector and so on.

Based on the above, the government is designing new mining raw which includes several policies such as activities of investment from overseas and division of profits between the investors and government. The new mining law would be improved with several undefined descriptions as defined articles.

(4) State of Mining Industries

Mineral resources of actual operating mines consists of coal, gold, titanium, zirconium, bauxite, gem, limestone, and aggregate (Table 3.27). Among these, coal mines are located in Tete Province, gold mines in Manica Province, titanium and zirconium mine, gem mine and bauxite mine are located in Nampula Province.

There are not many operating mines at the moment. However, major class coal mines are waiting to start operations. Moatize Coal Mine operated by Vale commenced mining in 2011. In the future, Rio Tinto and other mining companies are supposed to start their coal mines. Additionally, many mining and exploration companies have active exploration projects such as gold in Manica, uranium in Tete and REE in central to northern parts of the country. On the other hand, oil and gas exploration projects are also booming offshore. Thus, Mozambique has a high possibility of becoming a supplier of energies such as coal, oil and gas.

Current main exploration projects in Mozambique are shown in Table 3.28.

Table 3.27 List of Operating Mines

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
1	Monarch	Companhia Mineira de Gile, Metais de Moçambique (Angola)	Manica Province	Au	OP	2008 - suspend	720 kg/y	Au	-	-
2	Minas Moatize	Beacon Hill Resources PLC	Tete	Coal	OP	2010 -	0.24 Mt/y	coal	-	-
	Moatize	Vale	Tete	Coal	OP	2011 -	11 Mt/y	coal	-	-
3	Morropino	Noventa Ltd	Zambezia Province	Ta	UG	2009 -	150 t/y	Ta2O5	-	-
4	Muiane	Pacific Wildcat Resources Corp. (Canada)	Zambezia, Province	Ta	UG	2011 -	340 t/y	Ta2O5	-	-
5	Monte Snuta	EC Meikles (Zimbabwe)	Monte Snuta	Al	OP	? -	0.12 Mt/y	bauxite	-	-
6	Moma	Kenmare Resources plc (Ireland)	Nampula Province	Ti, Zr	OP	? -	0.80 Mt/y 0.01 Mt/y 4 Mt/y	ilmenite rutile zircon	-	Tailing dam washed out at 2010
7	Ancuabe	AMG Mining AG (Germany)	Ancuabe	Graphite	OP	? -	0.01 Mt/y	graphite	-	-
8	Quarry Pemba	Marmonte Moçambique	Pemba	Marble	OP	? -	1500 t/y	marble	-	-
9	Mafiana	Minerais Industriais de Moçambique Lda	Mafiana	Bentonite	OP	? -	0.03 Mt/y	bentonite	-	-
12	Matola	Cimentos de Moçambique SARL	Matola	Ls	OP	? -	1.3 Mt/y	cement	-	-
13	Dondo	Cimentos de Moçambique SARL	Dondo	Ls	OP	? -	0.24 Mt/y	cement	-	-
14	Nacala	Cimentos de Moçambique SARL	Nacala	Ls	OP	? -	0.12 Mt/y	cement	-	-
15	Mutamabarico	Cimentos de Nacala S.A.	Nacala	Ls	OP	? -	0.35 Mt/y	cement	-	-

Table 3.28 State of Exploration in Mozambique (JOGMEC)

Stage	No	Name of Project	Kind of Elements	Proprietor, etc.
Develop-ment	1	Marropino	Ta	Noventa Ltd. (100)
F/S	2	Manica	Au	Pan African Resources plc. (100)
Drilling	3	Mundonguara	Cu, Au, Ag	Baobab Resources plc. (100)
	4	Niassa	Au, Ti	-
	5	Tete	Fe, Ti, V, Mn	Baobab Resources plc. (85), International Finance Corp. (15)
Geo-physical	6	Chadzuca	Au	Noise Media Inc. (50), Head4 Solutions Inc. (50), Viceroy Exploration Ltd. (1.50)
	7	Evate	P	Vale SA (100)
	8	Mavita	Ni	AXMIN Inc. (100)
	9	Mavuzi	U	Jacana Resources Ltd. (80), North River Resources plc. (20)
	10	Mount Muambe	La	Globe Metals and Mining Ltd.
Pre-liminary	11	King Solomon	Cu, Au, Ag	African Queen Mines Ltd. (100)
	12	Mimosa	Au	ABM Resources NL (76.33), Local Interest (23.67)
	13	Tulo	Au	Gold One International Ltd. (100)
	14	Zambezi Valley	U, Cu, Au	ARMZ Uranium Holding Co. (100)

(5) Role of Organization in Charge of Geology and Ore Deposits

National Directorate of Geology comes under the Ministry of Mineral Resources. The directorate was reorganized on October, 2013. It is divided into two organizations; National Directorate of Geology and Geological and Mining Institute with the National Directorate of Geology in charge of the task for administration and the Geological and Mining Institute in charge of the technical task such as regional geology, exploration and engineering geology. However, actual organization of the sector is not changed at the moment, with related staffs working in the same office.

The main tasks of the directorate and institute consist of geological survey, mineral resources exploration including coal and other energies and geophysical exploration. There are engineers including 15 geologists, 1 geophysicist, 5 chemists and 6 GIS engineers. Hydraulic geologists are also included in the geologists.

They do not have obligations of operations for mine environment and safety. However, the directorate realizes the importance of hydraulic geological terrain in respect to mine environment to increase the number of operating mines in the future. Additionally, they understand that geologists belonging to the Council for Geoscience of South Africa have been conducting hydrogeological study in respect to the mine environment.

(6) International Cooperation, etc.

There are support programs from the environmental sector of Germany and WB to the National Directorate of Mines. These programs consist of funding support and capacity building for the environment related sectors in Mozambique which covers not only the National Directorate of Mines but also other sectors.

There are no international supports for project from overseas agencies or enterprises to the National Directorate of Geology. On the other hand, the staffs of the directorate have participated in short-term training in mineral resources exploration organized by JICA, JOGMEC and HIDA. Many participating engineers from the directorate visited Japan. Total of 39 geologists (2 geologists in 2013) have participated with the remote sensing training program in Botswana Remote Sensing Center.

As to support by training scheme from overseas, there are training programs in respect to geology and mining organized by Jindal Steel & Power, an Indian company and by mining sector of Australian which includes to completing master's and doctor's course.

3.6.4 Environmental Policy and State of Environment

The Environment Department is part of the National Directorate of Mines in the Ministry of Mineral Resources and National Directorate of EIA is part of the Ministry of Environment and are in charge of mine environment management. Both departments are collaboratively conducting approval and license of EIA. Environment Department of the National Directorate of Mines commenced operation in 2002 and the National Directorate of EIA commenced operation in 1998. They are also working together with the Ministry of Labor and the Ministry of Health.

(1) Organization in Charge of Environment

Organization chart of the National Directorate of EIA as environmental department is shown in Figure 3.36.

(2) Laws, etc. relating to Environment

Related laws and regulations for mine environment is the Environmental Law (established in 1997 and revised in 2004) and the Environmental Quality and Effluent Emission Norms (established in 2004). Related guidelines and procedures in the sectors are not set up in the department at the moment.

In relation to environmental regulation, government has been using original standards as to discharged water and ground water.

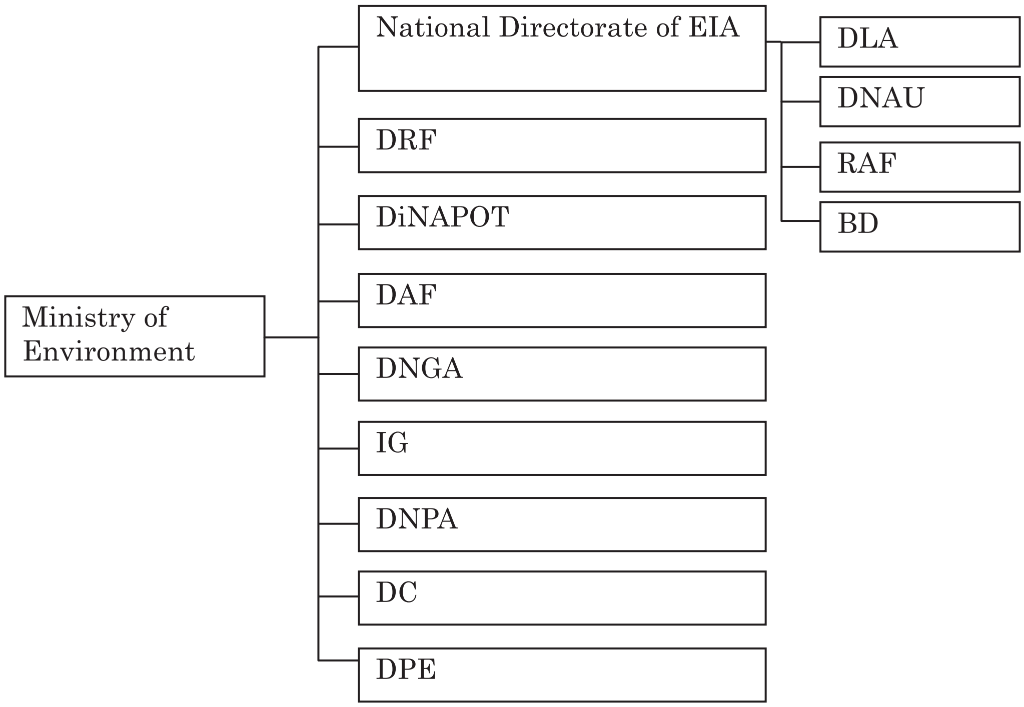


Figure 3.36 Present Organization Chart of the Ministry of Environment

(3) International Cooperation, etc.

Assistance to mine environment from overseas include funding support program by Germany and capacity building by WB. Based on these, creation program of guideline for auditing and monitoring in respect to EIA work in National Directorate of EIA was started in 2012. On the other hand, there is no direct assistance program to Environment Department of National Directorate of Mines. Additionally, environmental engineers of the National Directorate of EIA have been participating in short-term training for mining supported by JOGMEC. In spite of that, environmental engineers of Environment Department of the National Directorate of Mines have not participated in the training so far.

3.6.5 Environmental Policy and Condition

(1) Mine Environment

There are no notable mine pollutions in EIA approved operating mines. However, water and soil contamination around small-scale mines for placer gold, air and soil contamination from tailing of abandoned uranium mine and dust in coal mine are recognized as concerning issues. Among these, small-scale mines for placer gold are the most concerned case due to the use of mercury to extract the gold.

(2) Occurrence and Potential of Mine Pollution

Illegal small-scale mines for placer gold are recognized as the most concerning site regarding mine environment. The sites are located in Manica Province, Nampula Province and Zambesi watershed. Illegal miners are using mercury to extract gold and it flows out to the river and contaminates drinking water. There are dams for drinking water near the mines and the rivers are changing to dirty color.

There are concerns about diffuse and soil contamination of radioactive element from the uranium tailing at the abandoned Mavuzi uranium mine in Tete Province. The mine was closed but uranium tailing remain at the place and inhabitants are gaining entry to the tailing. Another concern is the tailing dam in Moma titanium and zirconium mine at Nampula Province which gave way due to flashing in 2011 and the tailings flowed out and caused soil contaminated. Additionally, dust and exhaust gas in coal mines are also worrying.

(3) Damage Situation of Mine Pollution

There are no issues about mine pollutions emerging as a social issue so far. However, changes in color of river water around illegal small-scale mines are observed, where the illegal miners are using mercury to extract gold.

(4) Handling Mine Pollution

As counter measures for the concerned pollutions, the water contamination around small-scale mines of placer gold is left unsolved because of the difficulty in situation surrounding the mines. However, the government has considered the improvement plan. Regarding above, Swede private sector supported by WB carried out analysis of river water around the mine area on 2004 as a preliminary study. On the other hand, bilateral collaborative study project between Mozambique and Zimbabwe commenced as Pungoe River Management Project in 2012, where the target is to overcome the above issue of the mercury usage by illegal miners at gold small-scale mines. The study area is along the Pungoe River where the river flows through near the boundary between Manica and Tete.

The concern about diffuse and soil contamination of radioactive element from the uranium tailing at the abandoned Mavuzi uranium mine, IEA carried out sampling of the soil and measurement of level of the radiation, however, the results was not published as a report.

Regarding dust and exhaust gas in coal mines, government has not much worry about this due to the owners being major companies, such as Vale and Rio Tinto, and the enterprises are making an effort for improvement.

3.6.6 State of Counter measure and Monitoring for Mine Pollution

(1) Mitigation Plan for Mine Pollution

As a case of counter measure to the suggested potential in the abandoned uranium mine, government constructed fences to forbid people to enter and to protect their health. For the concern about mercury pollution around the illegal small-scale mines at Tete Province, both government of Mozambique and Zimbabwe commenced a collaborative study to overcome the issue. Thus, related governments have been conducting counter measures for these sites, however, these concerns are not running into the mitigation.

(2) Monitoring around Mine Pollution Site

Environment Department of the National Directorate of Mines and National Directorate of EIA are conducting audit and monitoring works at the concerned sites together with both sectors. However, audit and monitoring are based on visual observation and they do not perform measurement and analysis for the target materials such as water and soil. Additionally, there are no equipment and analysis instruments in both departments. Guidelines and procedures for audit and monitoring have not designed at the moment, thus, these works are based on the existing laws and regulations.

(3) International Cooperation, etc.

There are no actual assist from overseas in respect to reduce potentials of the mine pollution except the Pungoe River Management Project about mercury contamination between Mozambique and Zimbabwe in 2012.

3.6.7 Mine Safety

(1) Laws, etc. relating to Mine Safety

Related regulation for the mine safety is the Regulations Concerning Mining Operation Safety (established in 2006) and the revision of the document is still ongoing. Related guidelines and procedures in respect to the safety are not set up in the department at the moment.

(2) State of Mine Safety

Mine safety issues have occurred at small-scale mines in Manica, Zambezi and Nampula Province. Common small-scale mines generally do not have measures for safety and the undefended styles are setting off fatal incidents by rock falling and blasting. Additionally, there are many remains of mining such as shaft and drift in these places.

Moma titanium and zirconium mine at Nampula Province are well known as a latest major issue in respect to the safety, where the tailing gave way due to flashing. In this accident, a life was lost and local news dealt largely with the accident.

There is no archive for past mine incidents in the National Directorate of Mines. After this, major mining companies are supposed to start large-scale coal mining. Regarding these situation surrounding mining sector, the related departments will be needed to use technical knowledge, guideline and procedure in respect to management of mine safety. The departments also have a realization of the necessity of the related matters.

3.6.8 Present State of Human Resources Development and Request for Technical Training

(1) Present State of Human Resources Development

There is no original system about human resources development. Related engineers are obtaining their skills by on the job training. According to the current situation, there are requests to have human resource development programs such as long-term training in Japan by JICA.

(2) International Cooperation, etc.

There are assistance programs in respect to the human resources development supported by the Japanese, Australian and Indian governments. Among these, National Directorate of Mines, National Directorate of Geology and National Directorate of EIA have participated in short-term training in respect to the mineral resources exploration and mining organized by JICA, JOGMEC and HIDA. Many participating engineers the directorate visited. Total 39 geologists (2 geologists in 2013) have participated with the remote sensing training program in Botswana Remote Sensing Center.
As to support by training scheme, there are training programs in respect to geology and mining organized by Jindal Steel & Power, an Indian company and by mining sector of Australia which included to complete master's and doctor's course. However, these targeted engineers are mainly geologists of the National Directorate of Geology.

(3) Request on Technical Training in Japan

Related departments are strongly interested in attending long-term trainings in Japan. The technical contents which they want to acquire are as follows:

(National Directorate of Mines)
Technical items to acquire: technical knowledge of mine environmental EIA and management system of environment, method of monitoring and audit for mine environment, method of satellite image and GIS interpretation

Request for supports from JICA: creation of related guideline and procedure, assistance for establishment of analysis center and donation of equipment for monitoring and analysis, engineering resources development including long-term training

Training target person: several mining and environmental engineers in charge of audit and monitoring works

(National Directorate of EIA)

Technical items to acquire: technical knowledge of mine environmental EIA, method of monitoring and audit for mine environment

Request for supports from JICA: participation in long-term training including master's and doctor's course in respect to mine environment

Training target person: environmental engineers in charge of permission, audit and monitoring works

(National Directorate of Geology)

Technical items to acquire: addition of engineer and knowledge for geophysics, structural geology and mineralogy

Request for supports from JICA: participation in long-term training and engineering resources development for hydraulic geology in respect to mine environment and above terrains

Training target person: several geologists, geophysicists, chemists and GIS engineers in charge of geological and mineral exploration works

3.7 South Africa

3.7.1 Outline of South Africa

(1) Current State of National Affairs and Economic Indicator in South Africa

The current state of national affairs and the economic indicators of South Africa are:

- Area : 1,220,000 km^2 (Approximately 3.2 times of Japan, refer to Figure 3.37).
- Population : 50,580,000 people (in 2011, WB).
- Capital City : Pretoria.
- Races : Black, White, Colored, Asian.
- Languages : English, Afrikaan, Bantu (Zulu, Basotho, etc.).
- Major Industries : (Agricultural Products) Cattle, corn, citrus, fruits, wheat, sugar, wool, etc.
  (Mining Industry) Gold, diamond, platinum, uranium, ironstone, coal, copper, chromite, manganese, asbestos, etc.
  (Industries) Food products, iron manufacturers, chemicals, textile, automobile, etc.
- GNI (Gross National Income): US$ 408,200 million (in 2011: WB).
- GNI per person : US$ 6,960 (in 2011: WB).
- Rate of Economic Growth: 3.1% (in 2011: WB).
- Price Increase Rate: 5.0% (in 2011: WB).
- Total Amount of Trade: Export: US$ 97,100 million.
  Import: US$ 99,700 million (in 2011).
- Major Export Goods: Gold, rare metals, mineral products, chemical products, food products, textiles, diamond, etc.
- Major Trading Partner (in 2011):
    - Export : China, USA, Japan, UK.
    - Import : China, Germany, USA, Soudi Arabia.
- Currency : Rand (ZAR).
- Exchange Rate : US$ 1 ＝ Approximately 9.8 ZAR (in November, 2013).
- General Situation of Economy:

  South Africa occupies approximately three out of ten of the total GDP of Sub-Saharan African countries and it has been exerting traction on the African economy. The economy of South Africa has grown due to the mining sector, since the discovery of diamond and gold in the latter half of the 19th century. This led to expanding the manufacturing and finance businesses to use the mineral resources as underlying assets. However, the contribution of mining towards the GDP has degrading continually, with the peak of the rate recorded at 9.7% in 1990. On the other hand, the rate of finance and insurance businesses are expanding. The GDP in 2006 comprised of 2.7% in agriculture, 30.9% in mining and manufacturing, and 66.4% in service industry, with the rate of tertiary industry quite high similar to other industrial countries. However, the structure of economy in South Africa is dependent on the export of mineral resources and products. In contrast, the rate of imports for machineries occupies high portion.

South African economy stagnated by decrease of domestic consumptions and downturns of the world economy during 1997 to 1998. After the stagnation, the economy improved. However, the economy was slowed down again after 2002, because of high-interest rate and high value of the Rand. Based on the situation, South African Reserve Bank carried out a rate reduction of 5% in 2003. After this, prime rate took a slide to 11%; however, the high value of the Rand did not make improvement after the action. Economic growth in 2003 declined to 1.9% with the rate being 3.6% the year before. At the same time, the economic downturn reached bottom low at the second quarter and the financial policy was significantly relaxed. Based on these actions, domestic consumptions have recovered from the economic bottom and the economic growth rate reached 5.1% on 2007.

South African government has designed to GEAR (Growth, Employment and Redistribution) as a macro economic strategy, which is to liberalize the financial policy and trading, to return to healthy finance and to repeal related regulations in 1996. Since then, the country has had an economic growing trend. On the other hand, there are major social issues about unemployment. The rate is transitioning at the high level which over 20%.

The President Zuma has advanced priority issues of the middle period including the policy of acceleration of economic growing by his administrative policy speech in the house in June 2009.

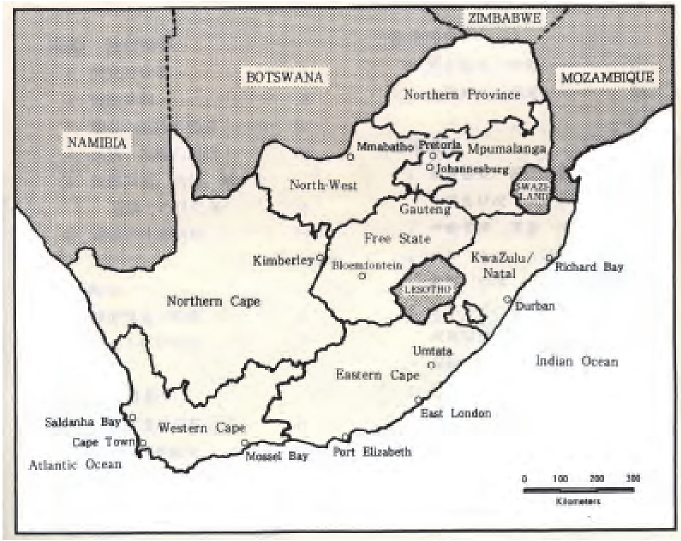
- Major Donor Country (in 2011, ODA): USA, France, Germany, UK, Norway, etc.
- Records of International Cooperation and Assistance by Japan:
  - (1) Onerous Financial Assistance (~2010) : ¥ 20,145,000,000 (Japanese Yen)
  - (2) Gratuitous Financial Assistance (~2010) : ¥ 13,196,000,000
  - (3) Technical Cooperation (~2010) : ¥ 8,672,000,000
- Local Administrative District: 9 states (Refer to Figure 9.1)

(2) State of Nature

a. Geographical Features

South African Republic is located in the Southern part of the African continent and the country has long coastal line with South Atlantic Ocean at southwestern part and Indian Ocean at southeastern part of the country (Figure 3.37). The capital city is Pretoria.

Lands of the country mostly consist of highland with a narrow coastal plain. On the other hand, inlands are comprised of broad flat terrains where population is few. Northwestern part of the country is located in the extended portion of the Namib Desert. Drakensberg Mountains is located in the east of the country, where Mt. Mahadi (3,450m) is located at the border between South Africa and Lesotho.



(JOGMEC, 2005)

Figure 3.37 Country of South Africa and Administrative Division

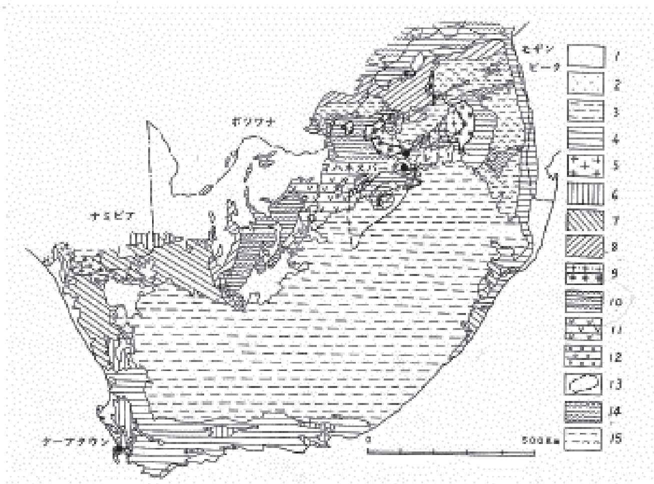
b. Geological Features and Mineral Deposits

Besement geology in the South Africa consists of Archean cratons with part of the aged approximately 37 Ga. Proterozoic and Phanerozoic stratums are also formed around the cratons (Figure 3.38). The oldest cratons consist of tonalitic gneiss and granitic rocks of the Swazian Erathem which corresponds to the basement rock of Early Archean.

Barberton and Murchson greenstone belt distribute east to northeast in the Kaapvaal craton. These greenstones have ophiolite succession. Witwatersrand System is comprised of shallow water sediments and the sedimental basin has gold deposits which are known as a largest gold producing place. The upper portion of the system consists of alternate layers of conglomerate and shale with gold and uranium.

Bushveld layered differentiated mass (complex) intrudes to Pretoria Group, which structures between both showing concordant structures. The complex is well known as the largest layered differentiated mass in the world and the complex notably involves rare metals such as chromite, PGM, titanium and vanadium.

Karroo System overlies basements such as Cape System of early to middle Paleozoic and Pre Cambrian basement. These lithologies consist of continental sediments and extend across southern parts of South Africa. There is no potential for metallic mineral resources in the stratum.



第 7-1 図　南アフリカ共和国の地質概略図（神谷, 1994 による）
1: 第四系，2: ウィッテンヘイジ系・ズルランド系, 3: カルー系, 4: ケープ系, 5: ケープ花崗岩類（1～5: 顕生代）, 6: ナミビアン系, 7: ナタールーナマクワランド系, 8: オリファントシェーク系・ソートパンスバーグ系, 9: ブッシュフェルトコンプレックス系, 上：珪長質岩・下：苦鉄質～超苦鉄質岩, 10: トランスバール系（5～10：原生代）11: ベンダースドープ系, 12: ウィットウォータースランド系, 13: ウィットウォータースランド系の潜在分布域, 14: スワジランド系（バーバトン緑色岩系, マーチスン緑色岩系）, 15: 古期片麻岩類（11～15: 始生代）

(JOGMEC, 2005)

Figure 3.38 Geology of South Africa

c. Climate

South Africa has summer from October to March and winter from May to August with the climate genial throughout the year.

3.7.2 The First Site Investigation

(1) Time Schedule on Site Investigation

The First Site Investigation in South Africa was carried out for five days from November 25 to November 29, 2013.

The time schedule on the first field investigation carried out is as shown in Table 3.29 (1) and Table 3.29 (2).

Table 3.29 Time Schedule on First Site Investigation in South Africa (1)

No	Month/Day	Time	Place	Item of Work	Persons met
1	Nov./24 (Sun)	-	Lilongwe (Malawi) - Johannesburg (South Africa)	Travelling.	
2	Nov./25 (Mon)	9:00 - 13:30 -	Pretoria: - DBSA Conference Room	Arrangement of information and preparation of investigation. Participation to the Water Workshop.	Speakers from enterprise
3	Nov./26 (Tue)	10:00 - 14:00 - 15:30 -	Pretoria: JICA Office Conference Room of Council for Geoscience Water Geosciences, Council for Geoscience	Courtesy and meeting on Investigation. Seminar, discussion and interview. Discussion and interview.	Assistant Representative and other Staff General Managers Hydro-geologists
4	Nov./27 (Wed)	8:30 - 12:00 - 15:00 -	Pretoria - Carolina: Water Geosciences, Council for Geoscience around Carolina around Witland	Meeting for site visit. Had a look around concerned dam. Had a look around Mine tailing.	Hydro-geologists Hydro-geologists Hydro-geologists
5	Nov./28 (Thu)	9:30 - 13:00 -	Pretoria: JICA Office Embassy of Japan in South Africa	Arrangement of meeting. Report on outlines of investigation.	JICA Staff First Secretary
6	Nov./29 (Fri)	9:00 - 14:00 - 15:30 -	Pretoria: Department of Water Affairs JICA Office PwC	Interview and discussion. Report on outlines of investigation. Interview and discussion.	General Manager and other Staffs Representative and other Staffs General Manager
7	Nov./30 (Sat)		Johannesburg (South Africa) - Maputo (Mozambique)	Travelling.	-

Table 3.29 Time Schedule on First Site Investigation in South Africa (2)

No	Month/Day	Time	Place	Item of Work	Persons met
1	Feb./18 (Tue)	7:00 - 14:30 -	Lusaka (Zambia) - Johannesburg Pretoria: JICA Office	Travelling. Meeting for visiting to related places.	Assistant Representative and other Staff
2	Feb./19 (Wed)	11:00 -	Pretoria: Department of Water Affairs	Interview and discussion.	Environmental engineer
3	Feb./20 (Thu)	8:00 -	Johannesburg: Au mines around Witwatersrand	Simple site visit.	-
4	Feb./21 (Fri)	14:00 -	Pretoria: Department of Mineral Resources	Interview and discussion.	Deputy director

(2) Governmental Organizations Concerned

The organizations and offices where the delegation visited and the governmental organization, department, division, etc. relating to the field investigation are as follows:

Place where the Delegation visited to:

- Embassy of Japan in South Africa

- JICA South Africa Office

Relating Governmental Organization, Directorate, Department, etc.:
- Mineral Policy and Promotion, Department of Mineral Resources
- Council for Geosciences
- Department of Water Affairs

(3) Holding of Seminar

Seminar in South Africa was held at a conference room in Council for Geoscience on 26 November. The participants of the Seminar reached four persons who consisted of managers from Geoscience Services, Minerals Development, Stakeholder and Business Development, and Marketing and Communication (Photo 3.36 and 3.37, Table 3.30).

In the seminar, the study team made three presentations. The presentations attracted interest from the participants. The manager of Geoscience Services explained about current situation of mine environment in the country and task of related government.

Photo 3.36 Council for Geosciences

Photo 3.37 Interview and Seminar with the Council for Geoscience (Participants reached four.)

(Explanatory Leaflet, etc.)

The seminar was carried out using the projector at the conference room. Presentation materials used in the seminar are:

1) Investigation in Africa - Explanation on Background of JICA: Activities of JICA, and
2) Investigation in Africa - Explanation on Mine Environment and Safety, Environmental pollution caused by mining and its counter measures, etc. in Japan, and
3) Investigation in Africa - Explanation on Japanese Experiences for Sustainable Mining in respect to Mine Environment and Safety.

(Questions and Answers)

There are questions and answers during the consultation included:

- Outline of mine environment in the South Africa
- Concerns and counter measures of mine environment in South Africa
- Outline of mine environmental study in Council for Geosciences

Table 3.30 List of Attendants to Seminar

No	Name	Organization / Division	Position
1	Gerhard Graham	Council for Geoscience	Executive Manager, Scientific Services
2	Maleka J Monyepao	Council for Geoscience	Manager, Stakeholder and Business Development
3	F. Ramagwede	Council for Geoscience	Executive Manager
4	Nthoubi Mdlvlijacka	Council for Geoscience	Marketing and communication
5	Mpho Pekane	JICA South Africa Office	Staff
6	Yoshimitsu Negishi	JICA Study Team	JICA Study Team
7	Hirohisa Kobayashi	JICA Study Team	JICA Study Team

3.7.3 Policy and State on Mineral Industries

(1) Directorate/Department and Organization in Charge

Department of Mineral Resources conducts authorization managements for exploration and operating mines, audit and monitoring works in respect to mining, mine environment and related safety. Among these, the department is collaborating the tasks with the Council for Geoscience and the Department of Water Affairs. The department is not in charge of approval and license work for EIA.

Technical divisions in the department consist of three divisions including Mineral Policy and Promotion, Mineral Regulation and Mineral Health and Safety (Figure 3.39, Photo 3.38 and 3.39).

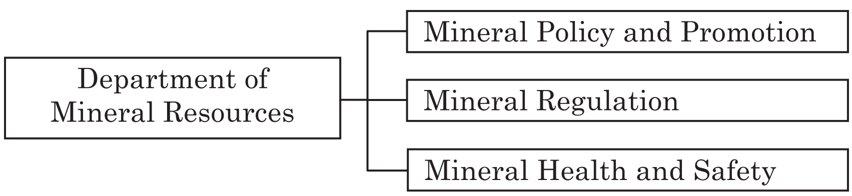


Figure 3.39 Present Organization Chart of the Department of Mineral Resources

Photo 3.38 Interview with Water Geosciences Division, Council for Geoscience (Twelve engineers in the Division)

Photo 3.39 Interview with Department of Water Affairs

(2) Laws, Acts and Regulations relating to Mining

Related law for mining in South Africa is Mineral and Petroleum Resources Development Act (established in 2002).

Related laws and regulations for the mine environment are Environment Conservation Act (established in 1989), National Environmental Management Act (established in 1998), and the National Water Act (established in 1998).

(3) Policy for Mining Industries

Important matters of mining policy of the actual government are to conduct accounts of mine safety policy, to conduct a review of BEE policy by mining charter and to consider availability of an organizing for national mining companies. There are several topics regarding mining policy. The first of these is to repeal applied absolutions in respect to applications for environmental study and exploration right regulated by the Mineral and Petroleum Resources Development Act, which is recognized in the AEMFC (African Exploration Mining Finance Corp) as a mining government corporation. The others are to commence high-value added plan for mineral resources such as gold, PGM, nickel, ironstone, chromite and so on, and to consider an introduction of carbon tax and others.

(4) State of Mining Industries

There are 6,000 mines including abandoned mines in South Africa. The minable minerals include gold, precious metals, chromite and manganese which are recognized as top class productions in the world, and coal, diamond, ironstone, copper, zinc, lead and others (Table 3.31).

Among these minerals, gold mines are concentrated in Witwatersland metallogenic province including Johannesburg. Precious metals and chromite mines are concentrated in Bushveld metallogenic province and Trasvaal metallogenic province which is located in north to northeast of Johannesburg.

Members of the Chamber of Mines of South Africa consists of 17 coal companies, 10 diamond companies, 4 gold companies, 19 ironstone companies, 10 manganese companies and others. Current mineral exploration activities are shown of Table 3.32.

(5) Role of Organization in Charge of Geology and Ore Deposits

Council for Geoscience has been conducting research activities in respect to geoscience and related applied terrain. Study and monitoring activities for the mine environment are performed by related researchers belonging to each division. The core divisions for mine environmental studies consist of Water Geosciences and Environmental Geosciences. These environmental studies and monitoring are carried out jointly with Department of Mineral Resources and Department of Water Affairs.

Organization of the Council for Geoscience is shown in Figure 3.40.

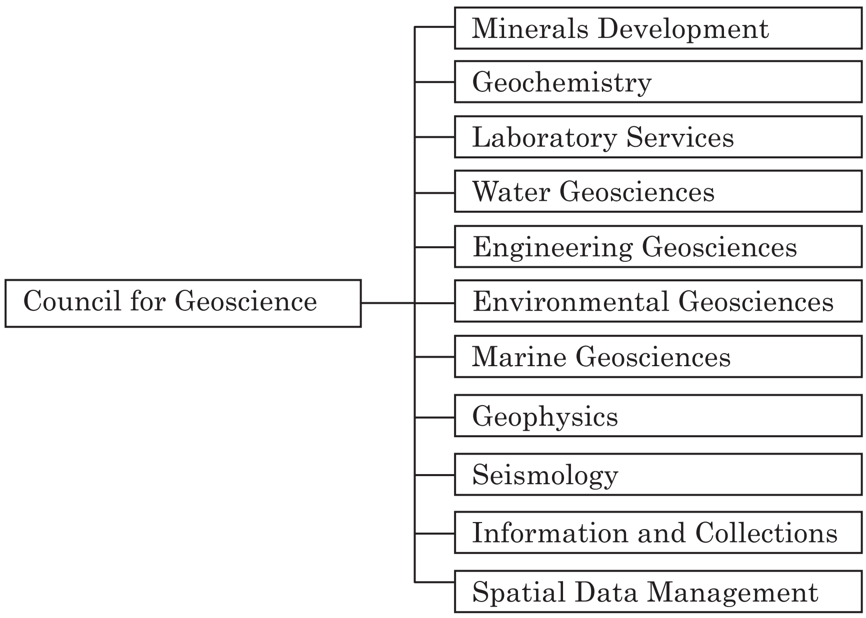


Figure 3.40 Organization of Council for Geoscience

Table 3.31 List of Operating Mines (1)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
1	Cons Murch	Consolidated Murchison Ltd. (Village Main Reef Ltd., 74%)	Gravelotte 50kms from Phalaborwa, in the Limpopo Province	Sb Au	UG	? -	7000 t/y	conc. of Au and Sb	-	
2	Thorncliffe	Xstrata plc(79.5), Merafe resources Ltd.(20.5)	Steelpoort	Cr	UG	? -	0.99 Mt/y	Cr	-	-
3	Kroondal	Xstrata plc(79.5), Merafe resources Ltd.(20.5)	Rustenburg 120km north-west of Johannesburg in North West Province	Cr	UG	? -	0.85 Mt/y	Cr	-	-
4	Helena	Xstrata plc(79.5), Merafe resources Ltd.(20.5)	23 km South of Steelpoort	Cr	?	2004 -	0.83 Mt/y	Cr	-	-
5	Waterval	Xstrata plc(79.5), Merafe resources Ltd.(20.5)	Rustenburg	Cr	UG	? -	0.65 Mt/y	Cr	-	-
6	Horizon	Xstrata plc(79.5), Merafe resources Ltd.(20.5)	Pilansberg in Limpopo	Cr	?	? -	0.26 Mt/y	Cr	-	-
7	Eastern Chrome	Samancor chrome Ltd. (international Mineral resources BV, 70%)	Steelpoort Valley, Mpumalanga in the Limpopo. 350km north-east of Johannesburg	Cr	UG	? -	2.0 Mt/y	Cr	-	-
8	Western Chrome	Samancor chrome Ltd. (international Mineral resources BV, 70%)	Mooinooi in the North West 130km north-west of Johannesburg	Cr	UG	? -	1.5 Mt/y	Cr	-	-

Table 3.31 List of Operating Mines (2)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
9	Bokfontein	Hernic Ferrochrome: Mitsubishi (51) Industrial Development (21), ELG Haniel GmbH(7.8), Mmakau Mining(6.5), Matlapeng Resources (6.5), International Finance(5),others(2).	40km west of Pretoria	Cr	UG	2010 -	1.5 Mt/y	Cr	-	-
10	Dwarsvier	African rainbow Minerals Ltd(50), Assore Ltd(50)	Mpumalanga Province	Cr	?	? -	1.4 Mt/y	Cr	-	-
11	Lesedi	international ferro Metals Ltd.	38 km WNW of Atteridgeville	Cr	UG	? -	1.32 Mt/y	Cr	-	-
12	Sky Chrome	International Ferro Metals	45 km West of Pretoria	Cr	?	? -	0.60 Mt/y	clude Cr	-	-
13	Nkomati Chrome	African rainbow Minerals Ltd(50), MMc Norilsk Nickel(50)	Mpumalanga Province	Cr Ni	UG	? -	1.0 Mt/y	Cr and Ni	-	-
14	Markana, Pandora	Lonmin plc	Rustenburg in the North West	Cr	UG	? -	0.81 Mt/y	Cr	-	-
15	Crocodile River	Eastern Platinum Ltd	near the town of Brits Arbourfell	Cr	?	? -	0.52 Mt/y	Cr	-	-
16	Rustenburg Chrome	Bayer (Pty) Ltd	14 km from Rustenburg	Cr	UG	? -	0.45 Mt/y	Cr	-	-
17	Bathopele, etc.	Anglo American Platinum Ltd. (Anglo American plc, 74.1%)	near the town of Rustenburg	Cr	UG	? -	0.43 Mt/y	Cr	-	-
18	Tharisa	Tharisa Minerals Ltd.	95 km north-west of Johannesburg and 35 km east of Rustenburg	Cr Pt	OP UG	? -	0.42 Mt/y	Cr	-	-
19	Dilokong	Dilokong chrome Mine (Pty) Ltd. [ASA	30 km North West of Burgersfort	Cr	?	? -	0.36 Mt/y	Cr	-	-

Table 3.31 List of Operating Mines (3)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
20	Palabora	Rio Tinto Ltd(57.7) Anglo American plc (16.8)	Phalaborwa	Cu	OP	? -	0.08 Mt/y	Cu	-	-
21	Bathopele, etc.	Anglo American Platinum Ltd. (Amplats)	Rustenburg	Cu	UG	? -	0.013 Mt/y	Cu	-	-
22	Nkomati	Nkomati Joint Venture	Mpumalanga Province	Cu	OP	? -	9000 t/y	Cu	-	-
23	Impala	Impala Platinum Ltd	near Rustenburg	Cu	UG	? -	6000 t/y	Cu	-	-
24	Black Mountain	Vedanta resources plc (74)	113km north-east of Springbok Northern Cape Province	Cu	?	? -	7000 t/y	Cu	-	-
25	Marikana and Pandora	Lonmin Plc Aquarius Platinum Ltd(50)(South Africa) , Rustenburg Platinum Mines Ltd(50)	12 km outside of Rustenburg	Cu	UG	? -	2000 t/y	Cu	-	-
26	Kopanang	Anglo American plc(41.8)	170km southwest of Johannesburg	Au	UG	? -	32100 kg/y	Au	-	-
27	Great Noligwa	Anglo American plc(41.8)	160km southwest of Johannesburg	Au	UG	? -	14600 kg/y	Au	-	-
28	Moab Khotsong	Anglo American plc(41.8)	160km southwest of Johannesburg	Au	UG	? -	11000 kg/y	Au	-	-
29	Vaal River (surface operations)	Anglo American plc(41.8)	?	Au	?	? -	5100 kg/y	Au	-	-
30	Mponeng	Anglo American plc(41.8)	between the towns of Carletonville and Fochville	Au	UG	? -	17000 kg/y	Au	-	-
31	Tau Tona	Anglo American plc(41.8)	Just south of Carletonville in Gauteng and about 70km southwest of Johannesburg.	Au	UG	? -	16000 kg/y	Au	-	-

Table 3.31 List of Operating Mines (4)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
32	Savuka	Anglo American plc(41.8)	70km southwest of Johannesburg	Au	UG	? -	12000 kg/y	Au	-	-
33	KDC	Gold fields Ltd	60 - 80 km west of Johannesburg	Au	UG	? -	36900 kg/y	Au	-	-
34	Beatrix	Gold fields Ltd	240 kilometers south-west of Johannesburg	Au	UG	? -	12800 kg/y	Au	-	-
35	South Deep	Gold fields Ltd	45km south-west of Johannesburg	Au	UG	? -	9200 kg/y	Au	-	-
36	Kusasalethu	Harmony Gold Mining co. Ltd.	75km south-west of Johannesburg	Au	UG	? -	9000 kg/y	Au	-	-
37	Phakisa	Harmony Gold Mining co. Ltd.	250km south-west of Johannesburg	Au	UG	? -	7000 kg/y	Au	-	-
38	Tshepong	Harmony Gold Mining co. Ltd.	250km south-west of Johannesburg	Au	UG	? -	7000 kg/y	Au	-	-
39	Doornkop	Harmony Gold Mining co. Ltd.	20km west of Johannesburg	Au	UG	? -	6400 kg/y	Au	-	-
40	Target 1 and 3	Harmony Gold Mining co. Ltd.	300km South-West of Johannesburg	Au	UG	? -	6000 kg/y	Au	-	-
41	Masimong	Harmony Gold Mining co. Ltd.	300km South-West of Johannesburg	Au	UG	? -	5100 kg/y	Au	-	-
42	Bambanani	Harmony Gold Mining co. Ltd.	300km South-West of Johannesburg	Au	UG	? -	3300 kg/y	Au	-	-
43	Evander	Harmony Gold Mining co. Ltd.	120km East of Johannesburg	Au	UG	? -	2800 kg/y	Au	-	-
44	Joel	Harmony Gold Mining co. Ltd.	300km South-West of Johannesburg	Au	UG	? -	2500 kg/y	Au	-	-
45	Unisel	Harmony Gold Mining co. Ltd.	400km South-West of Johannesburg	Au	UG	? -	2400 kg/y	Au	-	-
46	-do- (surface operations)	Harmony Gold Mining co. Ltd.	400km South-West of Johannesburg	Au	OP	? -	1800 kg/y	Au	-	-

Table 3.31 List of Operating Mines (5)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
47	Kalgold	Harmony Gold Mining co. Ltd.	300km West of Johannesburg	Au	OP	? -	1300 kg/y	Au	-	-
48	Unisel	Harmony Gold Mining co. Ltd.	400km South-west of Johannesburg	Au	UG	? -	810 kg/y	Au	-	-
49	Blyvooruitzicht	Village Main Reef Ltd.	80km South-West of Johannesburg	Au	UG	? -	4800 kg/y	Au	-	-
50	Crown	DRDGold Ltd.	?	Au	?	? -	4500 kg/y	Au	-	-
51	Ergo	DRDGold Ltd.	?	Au	retreatment	? -	1100 kg/y	Au	-	-
52	Burnstone	Great Basin Gold Ltd.	80km South-East of Johannesburg	Au	UG	? -	7900 kg/y	Au	-	-
53	Ezulwini	First Uranium Corp.	40km West of Johannesburg	Au	UG	? -	4400 kg/y	Au	-	-
54	-do- (mine waste solutions project)	First Uranium Corp.	?	Au	?	? -	2200 kg/y	Au	-	-
55	Buffelsfontein and Tau Lekoa	Village Main Reef Ltd.	160km South-West of Johannesburg	Au	UG	? -	5100 kg/y	Au	-	-
56	Modder East	Gold One International Ltd.	30km East of Johannesburg	Au	UG	? -	4700 kg/y	Au	-	-
57	Cooke Underground	Gold One International Ltd.	40 km West of Johannesburg	Au	UG	? -	3700 kg/y	Au	-	-
58	Randfontein Surface	Gold One International Ltd.	40 km West of Johannesburg	Au	surface	? -	1000 kg/y	Au	-	-
59	Barberton	Metorex Ltd.(54) Shanduka Resources (Pty) Ltd.(26)	250km East of Pretoria	Au	UG	? -	3200 kg/y	Au	-	-
60	East Rand Properietary	White Water Resources Ltd.	25km North-East of Johannesburg	Au	UG	? -	2700 kg/y	Au	-	-
61	Central Rand	Central Rand Gold Ltd.	Johannesburg	Au	UG	? -	1200 kg/y	Au	-	-
62	Black Mountain	?	Aggeneys	Pb		? -	0.54 Mt/y	Pb	-	-
63	Sishen	?	Sishen	Fe	?	? -	41.0 Mt/y	Fe	-	-
64	Thabazimbi	?	Thabazimbi	Fe	?	? -	2.7 Mt/y	Fe	-	-

Table 3.31 List of Operating Mines (6)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
65	Khumari	?	?	Fe	?	? -	10.0 Mt/y	Fe	-	-
66	Beeshoek	?	Postmasburg	Fe	?	? -	1.0 Mt/y	Fe	-	-
67	Palabora	?	Phalaborwa	Fe	?	? -	3.5 Mt/y	Fe	-	-
68	Mapochs	?	Roossenckal	Fe	?	? -	2.7 Mt/y	Fe	-	-
69	Vametco Vanadium	?	Near Brits	Fe	?	? -	1.1 Mt/y	Fe	-	-
70	Rhovan	?	Brits	Fe	?	? -	0.4 Mt/y	Fe	-	-
71	Nchwaning	?	Black Rock	Mn	?	?	5.0 Mt/y	Mn	-	-
72	Gloria	?	Black Rock	Mn	?	? -	0.6 Mt/y	Mn	-	-
73	Mamatwan	?	Hotazel	Mn	?	? -	3.5 Mt/y	Mn	-	-
74	Wessels	?	Hotazel	Mn	?	? -	1.0 Mt/y	Mn	-	-
75	Kalahari	?	?	Mn	?	? -	2.7 Mt/y	Mn	-	-
76	?	?	North West Province	Mn	OP	? -	0.02 Mt/y	Mn- dioxide	-	-
77	Bathopele, etc.	?	?	Ni	?	? -	0.03 Mt/y	Ni	-	-
78	Nkomati	?	Mpumalanga Province	Ni	?	? -	0.02 Mt/y	Ni	-	-
79	Impala	?	?	Ni	?	? -	6000 t/y	Ni	-	-
80	Marikana and Pandora	?	?	Ni	?	? -	4000 t/y	Ni	-	-
81	Kroondal	?	?	Pt	?	?	7.8 t/y	Pt, etc.	-	-
82	Modikwa	?	Makgemeng	Pt	?	?	4.2 t/y	Pt, etc.	-	-
83	Mogalakwena	?	Ga-Masenya	Pt	?	?	10.6 t/y	Pt, etc.	-	-
84	Mototo	?	Steelpoort	Pt	?	?	4.1 t/y	Pt, etc.	-	-
85	Impala	?	Phokeng, North West Province	Pt	?	? -	29.5 t/y	Pt, etc.	-	-
86	Marula	?	Bothashoek	Pt	?	? -	2.2 t/y	Pt, etc.	-	-
87	Mankara and Pandora	?	?	Pt	?	? -	24.9 t/y	Pt, etc.	-	-
88	Zondereinde	?	Northam	Pt	?	? -	9.4 t/y	Pt, etc.	-	-
89	Marikana	?	?	Pt	?	? -	2.7 t/y	Pt, etc.	-	-
90	Everest Platinum	?	Lydenburg	PT	?	? -	3.8 t/y	Pt, etc.	-	-
91	Blue Ridge	?	?	Pt	?	?	3.9 t/y	Pt, etc.	-	-

Table 3.31 List of Operating Mines (7)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)			Environmental Issues	Issues of Mine Safety
92	Pilanesberg	?	?	Pt	?	? -	5.4	t/y	Pt, etc.	-	-
93	Eland	?	Brits	Pt	?	? -	7.5	t/y	Pt, etc.	-	-
94	Bokoni	?	Sefateng	Pt	?	? -	4.1	t/y	Pt, etc.	-	-
95	Two Rivers Platinum	?	Near Steelpoort	Pt	?	? -	4.6	t/y	Pt, etc.	-	-
96	Crocodile	?	Arbourfell	Pt	?	? -	3.1	t/y	Pt, etc.	-	-
97	Nkomati	? ?	Mpumalanga Province	Pt	?	? -	3.4	t/y	Pt, etc.	-	-
98	Smoky Hills	?	?	Pt	?	? -	3.0	t/y	Pt, etc.	-	-
99	Germiston ?	?	Germiston, GautengProvince	Ag	?	? -		t/y	Ag	-	-
100	Richhards Bay ?	?	Richhards Bay	Ti	OP	? -	1280 125	t/y t/y	ilmenite rutile	-	-
101	Exxaro ?	?	Koekenaap	Ti	OP	?	540 25	t/y t/y	ilmenite rutile	-	-
102	KZN Sands	?	Richards Bay	Ti	OP	? -	1050 110	t/y t/y	ilmenite rutile	-	-
103	Vaal Rivers ?	?	Vaal Rivers, Klerksdorp	U	?	? -	3000	t/y	U oxide	-	-
104	Ezulwini	?	?	U	?	? -	100	t/y	U oxide	-	-
105	Mapochs	?	Lydenburg	V	?	? -	0.01 8	Mt/y	V pent- oxide	-	-
106	?	?	Witbank	V	?	? -	0.01 1	Mt/y	V pent- oxide	-	-
107	Rhovan	?	Brits	V	?	? -	0.01	Mt/y	V pent- oxide	-	-
108	?	?	Witbank	V	?	? -	5000	t/y	V pent- oxide	-	-
109	Krokodikraal	?	Brits	V	?	? -	3800	t/y	V pent- oxide	-	-
110	Magata	?	?	W	?	? -	2400	t/y	W- oxide	-	-
111	Black Mountain	?	Aggenery, Northern Cape Province	Zn	?	? -	0.04 1	Mt/y	conc. of Zn	-	-
112	RBM ?	?	Richards Bay	Zr	OP	?	0.30	Mt/y	conc. of Zr	-	-
113	Exxaro ?	?	Kockenaap	Zr	OP	? -	0.13	Mt/y	conc. of Zr	-	-
114	Hillendale	?	Richards Bay, Kwazulu Natal Province	Zr	OP	? -	0.05	Mt/y	conc. of Zr	-	-

Table 3.31 List of Operating Mines (8)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation		Produced Amount of Mining (Products)			Environmental Issues	Issues of Mine Safety
115	Palabora	?	Phalaborwa	Zr	OP	?	-	0.02	Mt/y	conc. of Zr	-	-
116	Palabora	?	Phalaborwa	Zr	OP	?	-	8000	t/y	sulfate of Zr	-	-
117	Venetia	?	Northern Province	Dia	OP	?		7500	TC/y	Dia	-	-
118	Kimberley sutface	?	Kimberley	Dia	OP	?		1500	TC /y	Dia	-	-
119	Voorspoed	?	?	Dia	OP	?	-	800	TC /y	Dia	-	-
120	Finsch	?	100km west of Kimberley	Dia	OP	?	-	2800	TC /y	Dia	-	-
121	Culliman	?	?	Dia	OP	?	-	1800	TC /y	Dia	-	-
122	Helam, etc.	?	?	Dia	OP	?	-	175	TC /y	Dia	-	-
123	Koffiefontein	?	Free State Province	Dia	OP	?	-	120	TC /y	Dia	-	-
115	Palabora	?	Phalaborwa	Zr	OP	?	-	0.02	Mt/y	conc. of Zr	-	-
124	Kimberley underground	?	Kimberley	Dia	UG	?	-	100	TC /y	Dia	-	-
125	Baken, etc.	?	?	Dia	OP	?	-	140	TC /y	Dia	-	-
126	Goedehoop, etc.	?	?	Coal	?	?	-	55.0	Mt/y	Dia	-	-
127	Grootegeluk	?	Limpopo Province	Coal	?	?	-	18.8	Mt/y	Coal	-	-
128	Matla	?	Mpumalanga Province	Coal	?	?	-	14.0	Mt/y	Coal	-	-
129	Arnot	?	Mpumalanga Province	Coal	?	?	-	5.0	Mt/y	Coal	-	-
130	North Block	?	Mpumalanga Province	Coal	?	?	-	3.3	Mt/y	Coal	-	-
131	Leeuwpan	?	Mpumalanga Province	Coal	?	?	-	3.0	Mt/y	Coal	-	-
132	New Clydesdale	?	Mpumalanga Province	Coal	?	?	-	1.4	Mt/y	Coal	-	-
133	Tshikondeni	?	Limpopo Province	Coal	?	?	-	0.42	Mt/y	Coal	-	-
134	Mafube	?	?	Coal	?	?	-	5.0	Mt/y	Coal	-	-
135	Syferfontein	?	?	Coal	?	?	-	9.7	Mt/y	Coal	-	-
136	Middelbult	?	?	Coal	?	?	-	8.5	Mt/y	Coal	-	-
137	Brandspruit	?	?	Coal	?	?	-	8.4	Mt/y	Coal	-	-
138	Bosjesspruit	?	?	Coal	?	?	-	8.2	Mt/y	Coal	-	-
139	Twistdraai	?	?	Coal	?	?	-	6.4	Mt/y	Coal	-	-

Table 3.31 List of Operating Mines (9)

No	Name of Mine	Proprietor (Ratio)	Location	Kinds of Minerals	Mining Method	Period of Mine Operation	Produced Amount of Mining (Products)		Environmental Issues	Issues of Mine Safety
140	Mooikraal	?	?	Coal	?	? -	2.0 Mt/y	Coal	-	-
141	Middelburg	?	?	Coal	?	? -	18.5 Mt/y	Coal	-	-
142	Khutala underground	?	?	Coal	UG	? -	15.1 Mt/y	Coal	-	-
143	Klipspruit	?	?	Coal	?	? -	8.0 Mt/y	Coal	-	-
144	Impunzi ?	?	Witbank	Coal	?	? -	9.4 Mt/y	Coal	-	-
145	Tweefontein ?	?	Witbank	Coal	?	? -	6.2 Mt/y	Coal	-	-
146	Goedgevonde n	?	Witbank	Coal	?	? -	6.0 Mt/y	Coal	-	-
147	Mpumalanga ?	?	Breyten and Ermelo	Coal	?	? -	2.8 Mt/y	Coal	-	-
148	Optimum	?	?	Coal	?	? -	13.5 Mt/y	Coal	-	-
149	Koornfontein	?	?	Coal	?	? -	5.2 Mt/y	Coal	-	-
150	Graspan, etc.	?	?	Coal	?	? -	7.0 Mt/y	Coal	-	-

Table 3.32 State of Exploration in South Africa (1) (JOGMEC)

Stage	No	Name of Project	Kind of Elements	Proprietor, etc.
Develop-ment	1	Bakubung	Pt, Pd, Rh, Au, Ni, Cu	Wesizwe Platinum Ltd(100)
	2	Booysendal North	Pt, Pd, Rh, Au	Northam Platinum Ltd(100)
	3	Buffelsfontein Uranium	U	First Uranium Corp(100)
	4	Elandsfontein PTM JV	Pt, Pd, Rh, Au	Platinum Group Metals Ltd(74), Wesizwe Platinum Ltd(26)
	5	Magareng	Cr	Xstrata plc(79.5), Merafe Resources Ltd(20.5)
	6	Mareesburg 8 JT	Pt, Pd, Rh, Au, Cu, Ni	Eastern Platinum Ltd(87), Lion's Head Platinum (Pty) Ltd(13)
	7	Maseve	Pt	Platinum Group Metals Ltd(74), Wesizwe Platinum Ltd(26)
	8	Mecklenburg Chrome	Cr, Fe	Chromex Mining plc(74), Umnotho We Sizwe Diamond Company Pty Ltd(26)
	9	Ryst Kuil	U, Mo	Areva NC(74), Lukisa Invest 100 Pty Ltd(8.75), Local Interest(17.25)
	10	Twickenham	Pt, Pd, Rh, Au, Cu, Ni	Anglo American Platinum Ltd(100)
	11	Zaaiplaats	Sn	Centurion Gold Holdings Inc(100)
F/S	12	Ergo Uranium	U	Ergo Mining Operations (Pty) Ltd(100)
	13	Everest North	Pt, Pd, Rh, Au	Sylvania Platinum Ltd(50), Aquarius Platinum Ltd(50)
	14	Gamsberg	Zn, Pb, Mn, Fe	Sterlite Group(74), Exxaro Resources Ltd(26)
	15	Genorah Farms	Pt, Pd, Rh, Au	Nkwe Platinum Ltd(24), Xstrata plc(50), Genorah Resources Pty Ltd(26)
	16	Grass Valley	Pd, Pt, Ni, Cu, Rh, Au	Sylvania Platinum Ltd(75), Impala Platinum Holdings Ltd(25)
	17	Grootboom	Pt, Pd, Rh, Au, Ni, Cu	Platmin Ltd(72.39), Moepi Capital Pty Ltd(27.61)
	18	Kalplats	Pt, Pd, Au	Platinum Australia Ltd(49), African Rainbow Minerals Ltd(51)
	19	Leeuwkop 402JQ	Pt, Pd, Rh, Ru, Ir, Au	Impala Platinum Holdings Ltd(74), Bakwena Ba Mogopa(26)
	20	Mphahlele's Location	Pt, V, Pd, Au, Ni, Cu	Platmin Ltd(54.29), Moepi Capital Pty Ltd(20.71), Limpopo Development Corp(20), Mphahlele Community Development Trust(5)
	21	Phosiri	Pt, Pd, Rh, Au, Ni, Cu	Lesego Platinum Mining Ltd(100)
	22	Project 5M	U, Au	Gold Fields Ltd(100)
	23	Rooderand	Pt, Pd, Rh, Au, Cu, Ni	Platinum Australia Ltd(70), Atla Mining Resources Pty Ltd(30)
	24	Ruighoek	Cr, Fe, Mg	Amcol International Corp(100)
	25	Sedibelo	Pt, Pd, Au, Rh	Bakgatla Ba Kgafela Community(50.1), Pallinghurst Resources Ltd(49.9)
	26	Sheba's Ridge	Ni, Cu, Pt, Pd, Au	Aquarius Platinum Ltd(65), Anglo American Platinum Ltd(35)
	27	Southern Free State Goldfield	Au, U	Witwatersrand Consolidated Gold Resources Lt(100)
	28	Styldrift 90JQ	Pt, Pd, Rh, Au	Anglo American Platinum Ltd(33), Royal Bafokeng Platinum(67)
	29	Tjate	Pt, Pd, Rh, Au, Ni, Cu	Jubilee Platinum plc(63), Matuba Holdings(37)
	30	Tubatse	Pt, Pd, Rh, Au	Nkwe Platinum Ltd(24), Xstrata plc(50), Genorah Resources Pty Ltd(26)
	31	Turquoise Moon	Fe	Ferrum Crescent Ltd(74), Mkhombi Investments (Pty) Ltd(26)
	32	West Rand Uranium	U	Mintails Ltd(100)
Drilling	33	Akanani	Pt, Pd, Rh, Au, Ni, Cu	Lonminplc(74), IncwalaResources(Pty)Ltd(26)
	34	Aurora	Pt, Pd, Ni, Cu, Pd, Ni, Cu, V, Fe	SylvaniaPlatinumLtd(75), ImpalaPlatinumHoldingsLtd(25),Matlala-A-Thaba
	35	Bauba	Pt, Pd, Rh, Au	BaubaPlatinumLtd(60), Unnamedcompany(40)
	36	Berg	Pt, Pd, Rh, Au	PlatfieldsLtd(100)
	37	Boikgantsho	Pt, Pd, Au, Ni, Cu	AngloAmericanPlatinumLtd(100)
	38	Bokfontein	Pt	NkwePlatinumLtd(100)
	39	BonAccord	Ni	AfricanNickelHoldingsLtd(74)
	40	BooysendalSouth	Pt, Pd, Rh, Au	NorthamPlatinumLtd(100)

Table 3.32 State of Exploration in South Africa (2) (JOGMEC)

Stage	No	Name of Project	Kind of Elements	Proprietor, etc.
Drilling	41	Cascade	Fe	MotjoliResources(100)
	42	DeWildt	Pt, Pd, Au	Xstrataplc(70),LocalInterest(30)
	43	DennyDalton	U, Au	LeopardResourcesNL(100)
	44	DerBrochen	Pt, Pd, Rh, Au, Cu, Ni	AngloAmericanPlatinumLtd(100)
	45	DilokongTailings	Pt, Pd	JubileePlatinumplc(100)
	46	EersteRegt	Pt, Pd, Rh, Au, Ni, Cu	LesegoPlatinumMiningLtd(45), Nebavest69(Pty)Ltd(50),SekokoResources(Pty)Ltd(5)
	47	Ga-Phasha	Pt, Pd, Rh, Au, Cu, Ni	AtlatsaResourcesCorp(51), AngloAmericanPlatinumLtd(49)
	48	Glenover	La, P, Nb, Sc	GlenoverPhosphateLtd(26.27), GalileoResourcesplc(73.73)
	49	GoldenValley	Ni, Cu, Pt, Pd	AfricanNickelHoldingsLtd(59),PlatminLtd(15), BlackEconomicEmpowermentCo(26)
	50	GovernmentGround	Pt, Pd, Rh, Au, Ni, Cu	LesegoPlatinumMiningLtd(40), Dyondisani-BolotolaMiningResourcesPtyLtd(60)
	51	Henkries	U	AardvarkUraniumLtd(74), BlackEconomicEmpowermentCo(16), AngloAmericanplc(10)
	52	Hoedspruit	Pt	AfarakPlatinum(Proprietary)Ltd(100)
	53	Imbasa-inkosi	Pt, Pd, Rh, Au	ImpalaPlatinumHoldingsLtd(53), PfulaInvestments(47)
	54	Jacomynspan	Ni, Cu, Pt, Pd, Au, Rh	AfricanNickelHoldingsLtd(74), Unnamedcompany(26)
	55	Kennedy'sVale	Pt, Pd, Rh, Au, Ru, Ir	BarplatsInvestmentsLtd(100)
	56	Kliprivier	Pt, Pd, Rh, Au	RealmResourcesLtd(95), MarangPlatinum(Pty)Ltd(5)
	57	Kruidfontein	Pt	AfarakPlatinum(Proprietary)Ltd(50), Unnamedowner(50)
	58	Liger	Pt, Pd, Rh, Au	PlatfieldsLtd(100)
	59	Loskop	Pt, Pd, Au, Ni, Cu	Lonminplc(50),PlatminLtd(22.39), LocalInterest(27.61)
	60	Magazynskraal	Pt, Pd, Rh, Au	PallinghurstResourcesLtd(33.35), BakgatlaBaKgafelaCommunity(46.65), AngloAmericanPlatinumLtd(20)
	61	Malelane	Fe	Ferrexplc(74),LocalInterest(26)
	62	MarulaMerensky	Pt, Pd, Rh, Ru, Ir, Au	ImpalaPlatinumHoldingsLtd(77.5), MmakauMining(7.5),TubatsePlatinumLtd(7.5), MarulaCommunityTrust(7.5)
	63	Millennium	Pt, Pd	AquariusPlatinumLtd(50),ImbaniPlatinumPtyLtd(50)
	64	Mokopane	Fe, V, Ti	BushveldMineralsLtd(64), BlackEconomicEmpowermentCo(36)
	65	Mokopane	Sn	BushveldMineralsLtd(100)
	66	Mooiplats	Pt, Pd, Rh	SylvaniaPlatinumLtd(74), SouthAfricanMiningDevelopmentCoPtyLtd(26)
	67	Naboom	Pt	CenturionGoldHoldingsInc(74), Unnamedcompany(26)
	68	Platreef	Pt, Pd, Au, Rh, Ni, Cu	Ivanplats(90),ItochuCorp(10)
	69	Postmasburg	Fe	BHPBillitonGroup(60),AngloAmericanplc(40)
	70	Potchefstroom Goldfield	Au, U	WitwatersrandConsolidatedGoldResourcesLt(60), AngloGoldAshantiLtd(20),GoldFieldsLtd(20)
	71	Rooderand/Ruighoek	Pt, Pd, Rh, Au	ChrometcoLtd(54),LocalInterest(46)
	72	Rooipoort	Au, Ni, Cu, Pt, Pd	CaledoniaMiningCorp(100)
	73	Rozynenbosch	Pb, Ag, Zn, Cu	Unnamedowner(100)
	74	SaltRiver	Cu, Pb, Zn, Ag, Au	ThabexLtd(100)

Table 3.32 State of Exploration in South Africa (3) (JOGMEC)

Stage	No	Name of Project	Kind of Elements	Proprietor, etc.
Drilling	75	SedibeloWest	Pt, Pd, Rh, Au	PlatminLtd(72.39),MoepiCapitalPtyLtd(27.61)
	76	Segalla	Ni	AfricanNickelHoldingsLtd(74), (Other share holdings are unclear.)
	77	Spitzkop	Pt, Pd, Rh, Au, Ru, Ir	EasternPlatinumLtd(50),SpitzkopPlatinumLtd(50)
	78	SpringbokFlats	U	HolGounInvestmentHoldings(Pty)Ltd(100)
	79	Steenkampskraal	La	GreatWesternMineralsGroupLtd(74), BlackEconomicEmpowermentCo(26)
	80	Thabazimbi	Fe	AquilaResourcesLtd(74), RakanaConsolidatedMiningPtyLtd(26)
	81	Tivani	Fe	FerroxHoldingsLtd(74), MboweniBrothersInvestmentHoldings(26)
	82	TPM	U	HarmonyGoldMiningCoLtd(100)
	83	Veremo	Fe, Ti, V	PetminLtd(25),KermasLtd(75)
	84	WarSprings	Pt, Pd, Ni, Cu,Au	PlatinumGroupMetalsLtd(70), WesizwePlatinumLtd(15),PlatminLtd(15)
	85	Waterberg	Pt, Pd, Au, Cu, Ni	PlatinumGroupMetalsLtd(49.9),JOGMEC(37), MnomboWethuConsultantsCC(13.1)
	86	Waterval	U, Mo	WesternUraniumPtyLtd(100)
	87	Zandkopsdrift	La	FrontierRareEarthsLtd(75), KoreaResourcesCorp(GovernmentofSouthKo(20), Unnamedowner(5)
	88	Zandrivierspoort	Fe	KumbaIronOreLtd(50),ArcelorMittalHoldingsAG(50)
	89	Zebediela	Ni, Fe	URUMetalsLtd(50),SouthernAfricaNickelLtd(50)
Geo-physical	90	Beestkraal	Pt, Pd, Rh, Au	Xstrataplc(100)
	91	Burgersfort	Ni	URUMetalsLtd(50),SouthernAfricaNickelLtd(50)
	92	Insizwa	Ni, Pt, Pd	XstrataCanadaCorp(Xstrata)(55), ImpalaPlatinumHoldingsLtd(45)
	93	Karoo	U, Mo	PeninsulaEnergyLtd(74), BlackEconomicEmpowermentCo(26)
	94	Mangalisa	Au, U	SuperiorMiningInternationalCorp(87), MiddelvleiGoldInvestments(Pty)Ltd(13)
	95	NorthernLights	Fe	MidwinterResourcesNL(70), NkgapuInvestmentsPtyLtd(30)
	96	PotgietersrusPlatreef	Pt, Ni, Cu, Co	ThabexLtd(100)
	97	RietfonteinFarm	Pt, Pd, Ni, Cu, Au	Ivanplats(50), AtlatsaResourcesCorp(50)
	97	RietfonteinFarm	Pt, Pd, Ni, Cu, Au	Ivanplats(50), AtlatsaResourcesCorp(50)
Pre-liminary	98	Aurora	Pt, Pd	SylvaniaPlatinumLtd(50), AngloAmericanPlatinumLtd(50)
	99	DRDlease	U, Au	WestWitsMiningLtd()
	100	Nonnenwerth	Fe	Ironveldplc(100)
	101	NorthernCape	Fe	AquilaResourcesLtd(74),Unnamedowner(26)

(6) International Cooperation, etc.

There are no international assistance and collaborative study in respect to mine environment in the Council for Geosciences. A mine environmental collaborative study with the Geosciences sector of Finland was carried out several years ago; however, the study did not involve actual field observations, where chemical analysis and interpretation was done.

3.7.4 Environmental Policy and State of Environment

(1) Organization in Charge of Environment

Department of Water Affairs and Department of Environmental Affairs is in charge of mine environment. The Department of Water Affairs conducts management, improvement and counter measure for drinking water in the country. For this reason, their terrains are extended to the mine environment field. The department is divided into National Water Resources, Policy & Regulation, Regions, International Water Cooperation. Specialized unit for mine environment and mine drainage water does not exist in the department, however, they organize study teams as the occasion arises. These study teams are carrying out their mine environmental study jointly with the Department of Mineral Resources and the Council for Geosciences.

Organization of the Department of Water Affairs is shown in Figure 3.41.

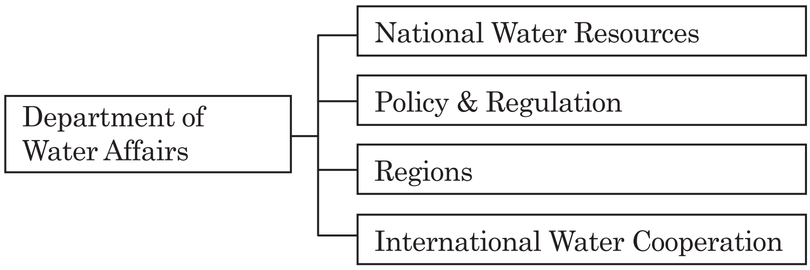


Figure 3.41 Department of Water Affairs

Department of Environmental Affairs conducts approval and license works of EIA for mine development and for counter measure of mine discharge water. The department is in charge of giving permission to other sectors such as management and monitoring for the mine environment.

Organization of the Department of Environmental Affairs is shown in Figure 3.42.

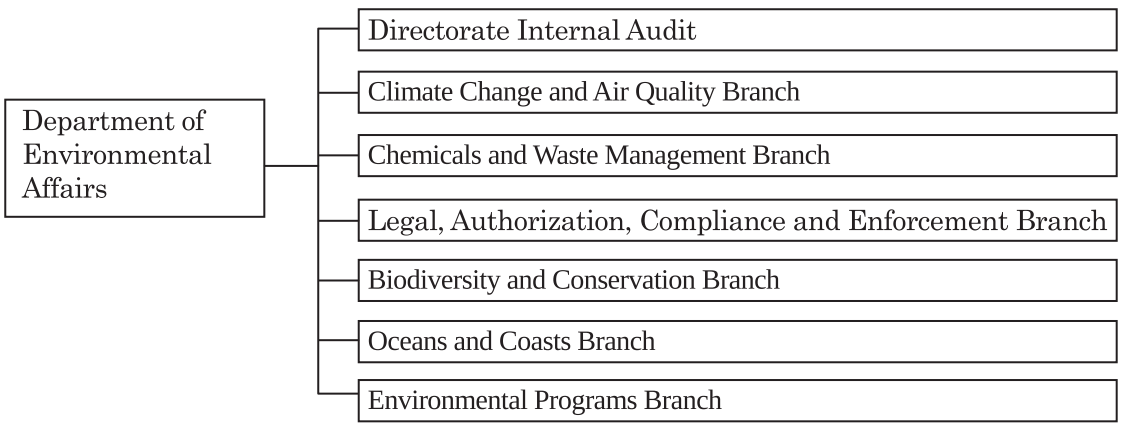


Figure 3.42 Department of Environmental Affairs

(2) Laws, etc. relating to Environment

Related law and the regulation for the mine environment are based on Environment Conservation Act (established in 1989), National Environmental Management Act (established in 1998) and National Water Act (established in 1998).

In addition to these environmental acts, there are guidelines and handbooks as supplements for actual execution by related sectors. Department of Water Affairs has opened a discharged water standard on their web site called Blue Drop / No Drop. The web page of Department of Water Affairs clarifies latest monitoring status for quality of drinking water around the country. The standard for drinking water used is the WHO standard.

(3) International Cooperation, etc.

Department of Water Affairs has been receiving technical proposals from international agencies to improve mine discharge water and others. These proposals have been from the USA, England, Finland, Japan, China, and Vietnam. These proposals are not for aid programs, but are actual business purposes.

3.7.5 Environmental Policy and Condition

(1) Mine Environment

There are a lot of concern with the greatest for overflow of acid from mine drainage to groundwater and tailings to river and/or soil. The mines consist of mostly gold, PGM, base metals, coal and uranium.

These concerns are well recognized by the general public and residents. For these reason, the Department of Mineral Resources, Council for Geosciences and Department of Water Affairs are performing collaborative studies and monitoring mine discharge water. However, the target sites have reached high, because of the number of mines including abandoned mines reaching 6,000 sites. In general, relatively large-scale mines are well managing mine drainage water on their own, however, middle to small-scale mines are not well managed. On the other hand, there are a lot of uncontrolled mines with no owners and management is not done.

(2) Occurrence and Potential of Mine Pollution

There are no major social issues in respect to mine environment so far. However, recently, there was an accident about contamination by acid water to a Carolina dam for drinking water which is located in coal mining area east of Pretoria (Photo 3.40, 3.41, 3.42 and 3.43). The accident became apparent after inhabitants who drank the water obtained from the dam complained of stomach pains. The pH of the dam water had reached approximately 3 when measured by inspectors of the town. Source of the leakage is not clear so far, however, several coal mines, which has tailings including pyrite in the shale, is located in the hinterland.

Abandoned gold mines of Witwatersland Mining Basins in southern part of the Johannesburg City are recognized are of prime concern. Approximately over 50 mines exist in the Basins. Numbers of shafts reach approximately 120 and the depth is over 2,000m. Most of the mines do not have owners, but some of the mines do. The issue of the Basins in respect to mine environment is that ground water level is continues to rise 10cm per day and the water changes to acid mine drainage, where surface and ground water are flowing into the inside pits. If the inflow will continue, the acid mine drainage from these mines will be overflow to Johannesburg City and Vaal River.

Additionally, there are concerns about contaminations of ground water and soil by acid mine drainage in PGM zone at Bushveld metallogenic province and Kruger National Park, and in KOSH gold field.

Photo 3.40 Simplified Water Analysis at Downstream of Carolina Dam (pH7.3)

Photo 3.41 Simplified Water Analysis in Carolina Dam (pH7.9)

Photo 3.42 Hydro-geologists of Council for Geosciences at Carolina coal mine

Photo 3.43 Tailing of Manganese Smelter at Witbank (The site corresponds to an abandoned coal mine)

(3) Damage Situation of Mine Pollution

There are no major social issues in respect to mine environment so far apart from that mentioned above, thus, the country has a lot of concern about the environment.

(4) Handling for Mine Pollution

Department of Mineral Resources, Council for Geosciences and Department of Water Affairs are conducting collaborative water monitoring and environmental study for the concerned sites around mines. Among these, the most focused study is the Witwatersland Mining Basins study to consider counter measures for the acid mine drainage issue. The study has been carried out jointly with these departments and includes monitoring study for ground water level, hydraulic modeling for underground and the consideration for counter measure for the Basin. The concept study was finished on 2013 and the F/S was already submitted to the Department of Environmental Affairs to obtain EIA authorization (Department of Water Affairs, 2013) (Figure 3.43).

Regarding public awareness, the Department of Water Affairs has information on water standards (latest monitoring status for quality of drinking water around the country) in their web site called Blue Drop / No Drop. Based on this information, people are able to decide for themselves whether the water is suited for drinking or not.

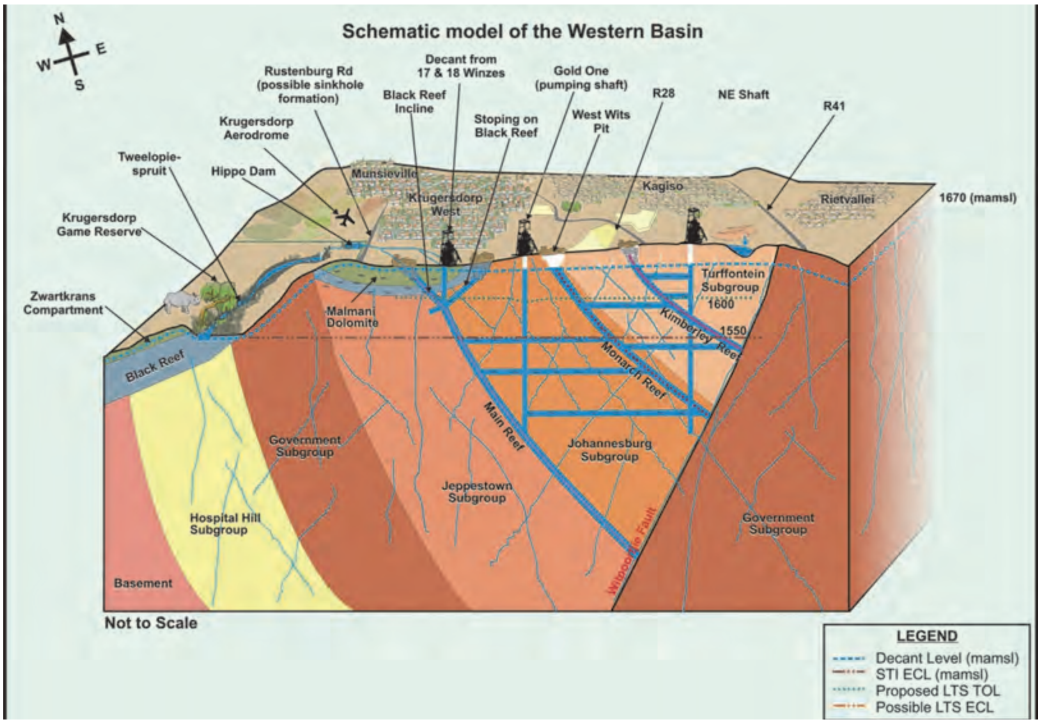


Figure 3.43 Hydrologic Analyses and Provision for Witwatersland Mining Basin created by Department of Water Affairs (Newsletter of Department of Water Affairs)

3.7.6 State of Counter measure and Monitoring for Mine Pollution

(1) Mitigation Plan for Mine Pollution

There are no mine pollution recognized by the related governments so far, however, sites of concern are located in a lot of places. To mitigate such concerns, the Department of Mineral Resources, Council for Geosciences and Department of Water Affairs are conducting monitoring and study works in the areas. The study area of Witwatersland Mining Basins is also a concerned site located in abandoned gold mines area at southern part of Johannesburg. The current plans for counter measure against acid mine drainage has been proposed to pump up and to discharge acid mine drainage from underground and to clean up the discharged water (Figure 3.43). The Department of Water Affairs is conducting on-site study at test plants to check up the degree of improvement for the mine drainage.

On the other hand, private sector mines are also making treatment facilities to mitigate concerns as their obligation. Additionally, Department of Mineral Resources, Department of Water Affairs and Council for Geosciences are conducting monitoring of water quality in the catchment area around the mines.

(2) Monitoring around Mine Pollution Site

High concentration sites of heavy metals and acid level are at several places. As stated earlier the Department of Water Affairs monitoring information on water quality on their web site for the public.

(3) International Cooperation, etc.

Regarding international assistance from overseas for counter measures for mine pollutions, the Department of Water Affairs has been receiving technical proposals from international agencies and other sectors from overseas in respect to improve mine discharge water and others. These proposed countries include the USA, England, Finland, Japan, China, and Vietnam. These proposals are not for aid programs, but actual business purposes.

There are no international support and cooperate programs in respect to the mine pollutions in the Council for Geosciences.

3.7.7 Mine Safety

(1) Laws, etc. relating to Mine Safety

Related law for mine safety is the Mine Health and Safety Act (established in 1996).

(2) State of Mine Safety

There are many underground mines in South Africa reaching mostly beyond a few thousand meters. Based on this, lot of accidents such as rock fallings involving loss of life have been happening at operating mines in the country. In 2007, Elandsrand Gold Mine had mine confinement with a few thousand victims. In another case, Tau Tona Gold Mine has frequently had accidents such as rock falling. In addition, few hundred fatal accidents and few thousand injuries have occurred.

On the other hand, there are a lot of issues for workplaces with strikes, insurgencies and shooting in respect to the demand for wage increase and so on.

Based on such current situations, the government, as supervisory agency is recognizing the importance of reducing this, and they started to organize the counter measures such as creating guidelines and procedures. However, these issues have not improved so far.

3.7.8 Present State of Human Resources Development and Request for Technical Training

(1) Present State of Human Resources Development

In the Council for Geosciences, 19 geologists (4 geologists in 2013) have participated with the remote sensing training program in Botswana Remote Sensing Center.

(2) Request on Technical Training in Japan

Water Geosciences division of the Council for Geosciences and the mine environmental study team of the Department of Water Affairs among the related departments in South Africa are interested in attending long-term trainings in Japan. The technical contents which they want to acquire are as follows:

(Water Geosciences division of the Council for Geosciences)

Technical items to acquire: hydrogeological knowledge of mine environment

Request for supports from JICA: upgrading of analytical capacity for acid mine drainage by conducting cooperative project which include donation of treatment facilities

Training target person: several research hydro-geologists

3.8 Madagascar

3.8.1 Outline of Madagascar

(1) Current State of National Affairs and Economic Indicator in Madagascar

The current state of national affairs and the economic indicator in Republic of Madagascar (here-in-after called Madagascar) are:

- Area : 587,000 km^2 (Approx. 1.6 times of Japan, refer to Figure 3.44).
- Population : 21,900,000 persons (in 2011: UNFPA).
- Capital City : Antananarivo (Population: Approx. 1,700,000 persons in 2010).
- Race(s) : People of African Continent, Malay people, No., of tribes: Approximately 18 (Merina, Betsileo, etc.).
- Language(s) : Malagasy Language and French (Both of them are official Language).
- Major Industries : (Agricultural and Stock breeding): Rice, coffee, vanilla, sugar, clove and cattle, (fishery products): Prawn, shrimp and tuna.
- GNI (Gross National Income): US$ 9,100 million (in 2011: World Bank).
- GNI per person : US$ 430 (in 2011: World Bank).
- Rate of Economic Growth: 1.0％ (in 2011: World Bank).
- Price Increase Rate : 9.5％ (in 2011 ： the World Bank).
- Total Amount of Trade: Export: US$ 1,530 million, Import; US$ 3,870 million (n 2012: EIU).
- Major Export Goods : Vanilla, crustacean and coffee.
- Major Trading Partner (in 2012 ： EIU):
    - Export : France, Indonesia, Singapore, China and Germany.
    - Import : China, France, South Africa, Singapore and Bahrain.
- Currency : Ariary.
- Exchange Rate : US$ 1＝Approximately 2,195 Ariary in April, 2012: EIU,
- General Situation of Economy: Agriculture is the major industry of Madagascar. The economy of Madagascar has reached a certain rate of economic growth since 1997 in accordance with the result of privatization of government managed enterprises, the revision of Investment Law, trade liberalization, etc. executed since mid-1990s. Although the political crisis in the former half of 2002 had serious influences to the economy, the economy of Madagascar has gradually recovered after that time from booming tourist business, etc. and active investigation in mining industry appeared due to the recent increase of petroleum price. As the major donors suspended their support to the provisional government inaugurated in March, 2009, financial stringency has occurred. The economic slump in tourist business and other industries became serious due to the afore-mentioned financial stringency.
- Major Donor Country (in 2010): France, U.S.A., Germany, Norway and Japan.
- Records of International Cooperation and Assistance by Japan ：
    （1） Onerous Financial Assistance (~2011, EN base) : ¥10,700 million (Japanese Yen),
    （2） Gratuitous Financial Assistance (~2011, EN base) : ¥63,403 million, and

（3）Technical Cooperation (~2011, JICA base)　　　: ¥16,817 million.

- Local Administrative District　　　：6 provinces, further divided into 22 districts.

(2) State of Nature

a. Geographical Features

Republic of Madagascar is an island situated southeast from African continent and in the western part of Indian Ocean. The island is ranked fourth in the world having its length of approximately 1,570 km and the width of approximately 580 km. The capital city of the country is Antananarivo (Figure 3.44).

In Madagascar, the mountain range is just under 3,000m above sea level extending from south to north through the center of island and the highest mountain is Mt. Maromokotro (height above sea level: 2,876m) situated north of the country.　There are tropical rain forests at the east side of mountain range, and forests and savannahs extend at the west side of the mountain range.　Deserts have developed at the south of the country and the vegetation of Baobab can be seen there.　There is a canal, which is natural, but partly man-made and is called Pangalans Canal, extending 460 ㎞ in its length at the east coast.　The capital city, i.e. Antananarivo is situated 1,300 m above sea level and paddy fields are extensively distributed.　Also, there are many bare land of laterite.

1. <u>Antanarivo Province</u>
2. <u>Antsiranana</u> Province
3. Fianarantsoa Province
4. Mahajanga Province
5. Toamasina Province
6. Toliara Province

(Google image)

Figure 3.44　Map of Madagascar and Administrative District

b. Geological Features and Mineral Deposits

(Geological Features)

Major areas of Madagascar Island are composed of shields of the Precambrian age which forms the Gondwana Continent and the Paleozoic layers. Madagascar Island had formed from the phenomena that land had separated from the African Continent caused by the disruption of Gondwana Continent of the later Jurassic Period and, in addition, the Indian Subcontinent was separated from Madagascar Island in the Upper Cretaceous Period. Madagascar Island is called the smallest continent in the world since the island is continuing as it is being isolated and since it has the unique fauna-and-flora of its own (Figure 3.45).

(Ore Deposits)

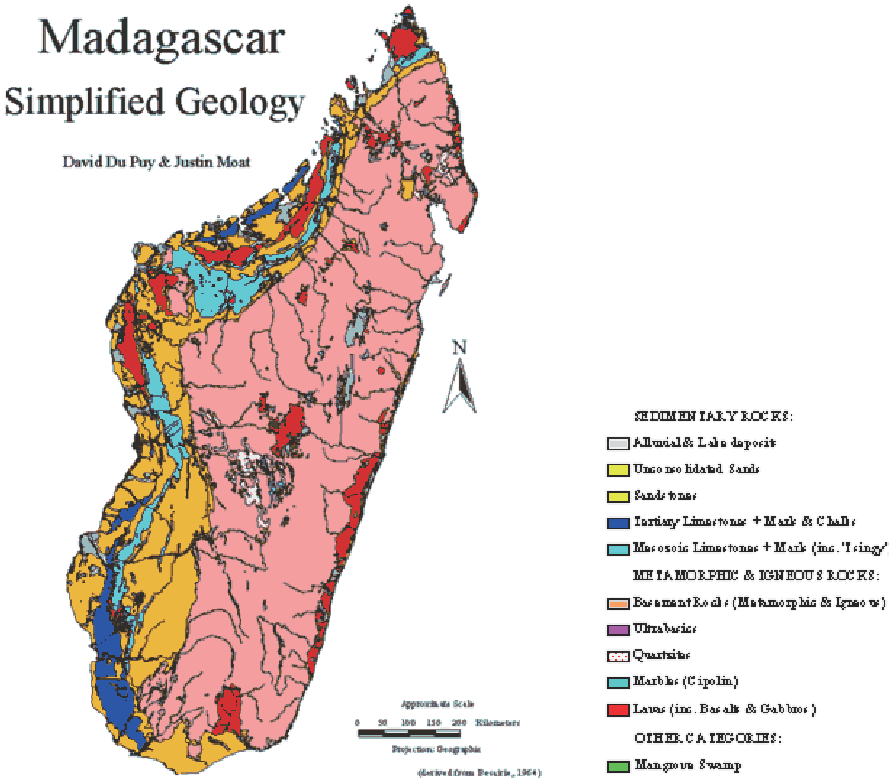
It is said that the underground resources in Madagascar have a high potential of mineral resources, especially rich resources of Au, Cu, Fe, Cr, nickel, Co, Al and Ti, and the exploration and development of such ore deposits has partly progressed. Also, the nonmetallic minerals, beryl, graphite, quartz and mica exist as nonmetallic resources. Ruby and sapphire deposits were found on 90's (Figure 3.46).

Current typical large-scale mines in Madagascar are Ambatovy nickel and cobalt Mine and Mandena ilmenite Mine. In these mines, production of the Ambatovy Mine is commenced on 2012 which operator is Sherritt International Ltd. and Sumitomo Corporation has also share of the mine. Rio Tinto has been operating from 2008.

c. Climate

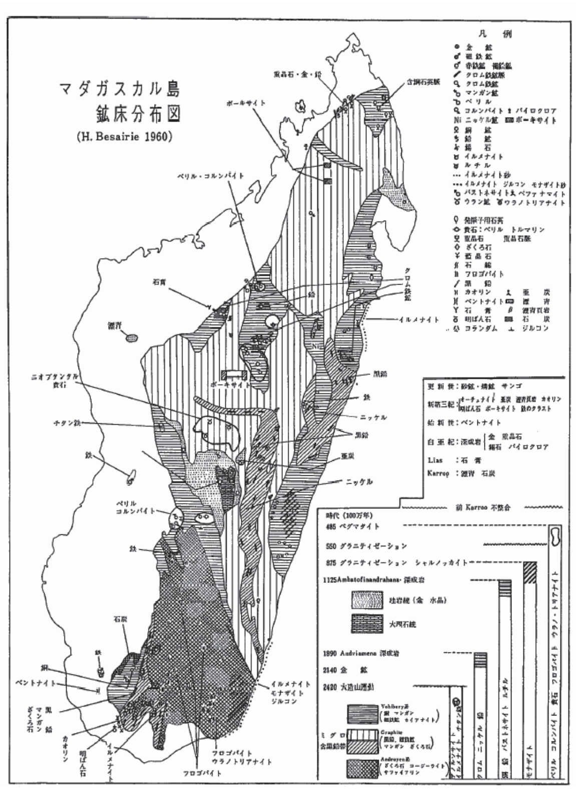
Whole land of Madagascar belongs to the tropical zone and however, the east part, the central part and the west part of island have different climatic conditions respectively due to the influence from the plateau existing at the center of island. In the winter season (from May to September), the east side of island has much precipitation due to the southeast trade winds, and on the contrary, the west side of island is dry. In summer season (from October to April), the precipitation in west side of island increases and the east side becomes dry due to the power increase of monsoon from the continental side.

Annual precipitation in the east side of the island is 2,000 to 3,500mm. And in the west is 500 to 1,500mm and differs considerably depending on the area. Also, the north part of island experiences cyclones some times.



（JOGMEC, 2005）

Figure 3.45　Geological Features of Madagascar



（JOGMEC, 2005）

Figure 3.46　Distribution of Main Ore Deposits in Madagascar

3.8.2 First Site Investigation

(1) Time Schedule on Site Investigation

The First Site Investigation in Madagascar was carried out for four days from February 24 to February 28, 2014.

The time schedule on the first field investigation carried out is as shown in Table 3.33.

Table 3.33 Time Schedule on First Site Investigation in Madagascar

No	Month/ Day	Time	Place	Item of Work	Persons met
1	Feb/23 (Sun)	-	Johannesburg (South Africa)- Antananarivo (Madagascar)	Travelling	-
2	Feb/24 (Mon)	9:00- 14:30- 15:00-	Antananarivo: JICA Office Ministry of Mines Directorate of Geology	 Meeting on investigation. Courtesy on investigation. Discussion and hearing.	 Project formulation adviser and others Chief of Staff and others Director and others
3	Feb/25 (Tue)	 9:00- 14:00-	Antananarivo: Directorate of Geology Directorate of Geology	 Seminar. Discussion and hearing.	 Chief of Staff and others Attendants: 19 persons from Madagascar Directors and others
4	Feb/26 (Wed)	 10:30- 15:00-	Antananarivo: Directorate of Geology Chamber of Mines	 Discussion and hearing. Discussion and hearing.	 Director and others Executive Secretary and others
5	Feb/27 (Thu)	 10:30- 13:00-	Antananarivo: Univ of Antananarivo (Department of Earth Sciences) National Office of Environment	 Discussion and hearing. Discussion and hearing.	 Director and others General Director and others
6	Feb/28 (Fri)	 8:30- -	Antananarivo: JICA Office Antananarivo (Madagascar)- Johannesburg (South Africa)	 Report on outlines of investigation. Travelling.	 Representative and others -

(2) Governmental Organizations Concerned

The organizations and offices which the delegation visited and the governmental organization, department, division, etc. relating to the investigation are as follows:

Place where the Delegation visited:
- JICA Madagascar Office

Relating Governmental Organization, Directorate, Department, etc.:
- Ministry of Mines
- Ministry of Mines: Department of Mines and Department of Geology

- Cahmber of Mines of Madagascar
- Department of Environment Assessment, Department of Quality and Communication and Department of Information of National Office of Environment
- Department of Earth Sciences, Faculty of Sciences, University of Antananarivo

(3) Holding of Seminar

Seminar relating to mine environment and safety is held in Meeting Room of Department of Geology, Ministry of Mines on Feb25 2014. The participants are gathered from each department of the Ministry of Mines and University of Antananarivo (Photo 3-44, 3-45).

Study team made their presentation of three files. The presentations attracted the interest of participants and related persons were expressed issues and challenges about mine environment and safety, which they were pointed out that related laws are needed to be revised and the small-scale miners are not equipped with PPE.

Related persons in the Ministry were expressed that Japanese experiences in respect of the countermeasures for mine environment are useful for future of mining sector in Madagascar and the sector need to be supported from Japanese related organization.

(Explanatory Leaflet, etc.)

The seminar was carried out by using the projector of the conference room. Presentation materials used in the seminar were three files, listed below:

1) Investigation in Africa - Explanation on Background of JICA: Activities of JICA, and
2) Investigation in Africa - Explanation on Mine Environment and Safety, Environmental pollution caused by mining and its countermeasures, etc. in Japan, and
3) Investigation in Africa - Explanation on Japanese Experiences for Sustainable Mining in respect to Mine Environment and Safety.

(Questions and Answers)

The issues brought up during the questions and answers during the consultation are as follows:

- Contents and categories of training scheme by JICA
- Management process of abandoned mine in Japan
- Challenge in the Department of Mines, which there are issues about digging in small-scale mines.
- Challenge in respect of mine environment, which there is no original standards and the related laws should be revised to deal with current mining situation.

Table 3.34 List of Attendees to Seminar

No	Name	Organization / Division	Position
1	RASOAMALALA Vololonirina	Ministry of Mines	Director of geology
2	RABEARY Gervais Alain	Ministry of Mines	Chief of staff
3	RAKOTOARIMANANA Pamphile	Ministry of Mines	General Secretary
4	RATSIMBAZAFY Felana	Ministry of Mines	Secretary
5	RANDRIANARISOA Filemona	Ministry of Mines	Director of Mines
6	RASOAMALALA Vololonirina	Ministry of Mines	Director of geology
7	RAVELONJATO Philippe	Ministry of Mines	Mining Service
8	RASAMIMANANA Georges	Ministry of Mines	Chief of Laboratory
9	RAKOTONDRAVALY Jean Desiré	Ministry of Mines	Director of Gold Section
10	RAZANAKOLONA H. Fenosoa	Ministry of Mines	Head of Departement (Geological & Mine)
11	NOMENJANAHARY Harivola	Ministry of Mines	Chief of environment section
12	RANDRIAMANANJARA Louis Hervé	Ministry of Mines	Responsible of Database Mining & geology
13	SAHOLIARIMANANA Voahanginirina	Ministry of Mines	Responsible of Research and Exploration
14	RAMANANDRAIBE Zonantenaina	Ministry of Mines	Responsible of Documentation and Cartography
15	RABEARISOA Harijaona	Ministry of Mines	Environnement
16	MAMINIRINA	Ministry of Mines	Chief of Department
17	RALISON Bruno	University of Antananarivo	Professor (Chief of Geosystem and evolution)
18	RAMBOLAMANANA Voahangy	University of Antananarivo	Professor (Head of Department Earth Sciences)
19	RAZAFIMANDIMBY Olivier	University of Antananarivo	Professor
20	RAMBELOSON Roger A	University of Antanananarivo	Assistant Professor
21	Kaoru TAKAHASHI	JICA Madagascar	Project Formulation Adviser
22	Yoshimitsu NEGISHI	JICA Study Team	-
23	Takayuki YOKOYAMA	JICA Study Team	-

Photo 3.44 Seminar at Department of Geology
(Madagascar side were participated 19 persons.)

Photo 3.45 Hearing from Department of Mines
and Department of Geology

3.8.3 Policy and State on Mineral Industries

(1) Directorate/Department and Organization in Charge

Managing organization in charge of mining in Madagascar is upon the Directorate of Mines and Geology of the Ministry of Energy and Mines. The organization system of the Directorate of Mines and Geology in 2005 is shown in Figure 3.47.

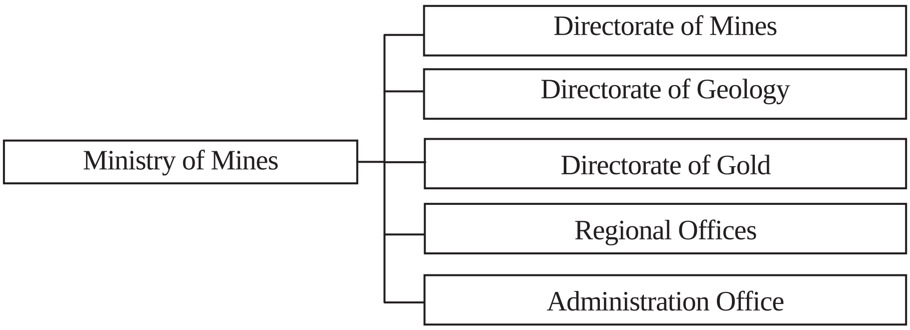


Figure 3.47 Organization System of the Directorate of Mines

The Directorate of Mines and Geology is composed of four departments including 1) Department of Mining Affairs, 2) Department of Inspection of Mines and Quarries, 3) Mining Laboratory and 4) Department of Geology, And administration sector consists of the Section of General Affairs and Finance, Section of Mine Environment, and Section of Statistics and Mining Royalty.

(2) Laws, Acts and Regulations relating to Mining Industries

New Mining Law and Regulation of Mining were enacted in 1999 and the Regulation of Application of Mining Right was successively enacted in 2000 (Table 3.35), after demise of socialist regime in 1990.

Table 3.35 Legislation related to the Mining Industry of Madagascar

No	Legislation related to Mining	Enacted Year	Main Components
1	(New) Mining Law	1999	-Staged license system of mining right (Free exploration license, Exclusive exploration license, Mining license). -Mining royalty. -Observance of environment. -Others.
2	Implementing Regulation for the (new) Mining Law	1999	-Implementing regulation of the (new) Mining Law. -Others.
3	Implementing Regulation for the Application of Mining Right	2000	-Regulation of application for various mining rights -Others.
4	Large-scaled Mine Investment Act	2004	-Regulation for the investment to large scaled mining.

The Implementing Regulation for the (new) Mining Law is staged license system. The exploration such as trenching and drilling can not be carried out during three month of First Stage under the free exploration license. The fee of free exploration license is US$ 5 per 2.5 acres.

All kinds of exploration activities can be carried out under the exclusive exploration license during three months of the Second Stage. The exploration right has the exclusive exploration license of 10 years, and it is possible to renew once for 5 years. The fee of exclusive exploration license is US$ 100 per 2.5 acres for the first year and US$ 150 per 2.5 acres for following year.

For the application of exploitation right, it is necessary to attach documents such as the Land reclamation plan, Environmental impact assessment report, Mine closure plan, etc. And then, the final stage is the exploitation license (mining right) for the mine operation.

The period of mining right is 40 years, it is possible to extend it many times by 20 years, however the commencement of operations has a time limit.

The royalty is 2% for the products of mine, and import tax is 10% for the commercial commodity. In addition, mining works are also covered with the obligations by the tax law, civil law and environmental law.

(3) Policy for Mining Industries

After the political change in 2009, the mining policy was also in chaotic condition due to political disarrangement; therefore most of the investors are watching a political condition.

Although the Government of Madagascar had indicated the necessity to review concerning several mining contracts in September, 2009, the government announced that there was no need to review mining contracts. Although the government had also announced to participate in large-scaled mining projects, definite mining plans by the government have not been announced yet.

(4) State of Mining Industries

Mining in Madagascar had not been fully carried out so far, even though Madagascar has high potential of mineral resources. Madagascar had enacted the Large-scaled Mine Investment Act as well as promoting mine development by foreign investment under the cooperation of World Bank in 2002 in order to make an impelling force for economic development of Madagascar. Ambatovy (Ni) Project was established in February, 2005 herewith by Canadian Dynatec (past: Sherritt International), and Sumitomo Corporation participated in this project in August, 2008 and the project was promoted to development. The mine was implemented to production on 2012. In December, 2008, QIT Madagascar Minerals (QMM: Rio Tinto 80%, Madagascar Government 20%) had commenced to produce ilmenite concentrate as a material of titanium.

Currently, main mining products consist of chromite ore and ilmenite concentrate, and potentials of mineral resources are confirmed to be Au, Ni, Co, Cu, Zn, Pt metal group (PMG), Al (bauxite), and uranium, coal and petroleum as energy resources. However, these mineral resources are not developed due to insufficient infrastructures.

Outline of each kind of mineral resources is shown as below.

(Au)
Numerous gold ore deposits are known in Madagascar, and main locations are Ampanihy in southern part, Andavakoera in northeastern part, Maevatanana at the eastern coast, and Miandrivazo in the western part of Madagascar. There is a possibility to produce 2 tons per year in total.

(Cu)
Medium to small-scale Cu ore deposits including Ambatovarahina, Besakoa and Daraina are confirmed in Madagascar. Ore reserves at Ambatovarahina are estimated to be 252,000tons and Cu content is 4.75%. It is possible to be developed as small-scaled mine.

(Fe)
Main Fe ore deposits are distributed at the sites near Soalala, Betioky and Fasintsra. Fe ore deposit near Soalala is estimated at 360 million tons as 35% Fe. Betioky ore deposit is estimated at 30 million tons as 24% Fe and 130 million tons as 14% Fe. Fasintsra ore deposit is estimated at 75 million tons as 36% Fe and 75 million tons as 34 % Fe.

(Cr)
Production of chromite ore in Madagascar is currently 10th in the world. The reserves of Chromite ore are estimated to be 2.28 million tons at Bemanevika, 0.7 million tons at Ankazotaolana and 0.9

million tons in other sites. The export amount in 1998 was 147,700 t, 9.12 million US$ in value, and to exporting 51% to Japan and 49 % to China.

(Ni, Co)

Ambatovy laterite deposit is known to be comparatively large scaled Ni ore reserves. This ore deposit is located along the national road between the capital and Tomasina. Basic exploration by Madagascar government and BRGM (France) took place from 1970 to 1972. Phelps Dodge (USA) had obtained the mining right in 1995 and had taken 52 million tons of 1.24% Ni and 0.09% Co by the mineral exploration. Possible ore reserves are 1.11% Ni and 0.1% Co. The laterite Ni deposit is extended to the eastern sea coast between Fenoarivo and Mananjary.

(Al: Bauxite)

Bauxite is found in the southwestern part of the country. Manantenia bauxite deposit, estimating to be 165 million tons of 41% Al_2O_3, is the most promising bauxite reserves. And Farafangana deposit is estimated to be 100 million tons of 37% Al_2O_3.

(Ti)

Madagascar is known to be a country of rich titanium reserves. Ilmenite containing titanium, Zircon and Monazite containing Rare earth element (REE) are found in the beach sand along the seashore of Tolagnaro District in the southeastern part of the country. Total ore reserves are estimated to be 11.6 million tons of 47 to 51% TiO_2 and 678 thousand tons of Zircon. In addition, Moromb, Tambohorano and northern area in the western seashore are also known as same sand ore deposits.

In the Talagnaro District, QIT-Fer et Titane, subsidiary of Rio Tinto, is planning a mine development. The survey of ore reserves, examination of development plan, environmental protection, etc. had been terminated until 1992 and the Environmental Permission of Environmental impact assessment (EIA) was obtained in November, 1991.

Non-Metal Group

(Be)

Beryl of 30 tons within the quartz in 1998 was produced in Madagascar. Large-scaled Beryl deposits in the pegmatite are found in the areas of Ambato-finadrahana, Mpandremaika Malakialina and Tsaratanana.

(C: Graphite)

Numerous ore deposits of graphite are found and are estimated to be 960 thousand tons as total reserves. Main miner is Etablissements Gallois, which has three mines including Ambatolampy, Mpanihy and Manampotsy located in the eastern sea shore. The graphite of 9,244 tons (value: 4.66 million US$) was exported to UK, Germany, USA, etc. for the refractory materials.

(Quartz)

Yellow quartz, industrial quartz, rose quartz and smoky quartz are produced in the country. Industrial quartz was discovered in the areas of Kaandreho, Mananara and Aroantsetra. Kaandreho quartz deposit is mined by Rollmine. The quartz deposits of Mananara and Maroantsetra are mined by Prexmin. 586 tons of quartz was exported to China, Russia and Germany in 1999.

(Mica)

Mica consists of phlogopite, and the phlogopite deposits are found in the areas of Ambarata, Ampandrandava, Benato and Maniry Miary. Mica was exported to Belgium (81%) and Japan (14%), etc. in 1999.

The list of mines in 2012 is shown in Table 3.36.

(5) Role of Organization in Charge of Geology and Ore Deposits

Directorate of Geology belongs to the Ministry of Mines. The main task of the department is to conduct geological mapping in the country and the geologists are performing the mapping to complete sectional geological maps of the country. However, number of the geologist consists of only five at the moment. There is no analysis facility in the department.

There is a challenge of the department which the department has to finalize scale 1:100,000 geological mapping in the country.

(6) International Cooperation, etc.

There is no international support from overseas agencies or enterprises to the above departments at the moment. However, Directorate of Geology had geological mapping and the compile project supported by World Bank during 2005 to 2012, which the project had implemented in scale 1:100,000 geological mapping in a part of the country and had compiled scale 1,000,000 geological map on the same duration. BRGM and USGS were joined in this project as well.

During 2008 to 2012, JICA had supported also their geological mapping of scale 1:100,000 as a project for improvement of structuring of geology and mineral resources information due to promotion for the mining sector.

For their training, engineers of Directorate of Mines have participated in mining training at University of Queensland in Australia. In recent days, one mining engineer was participated in remote sensing training at Japan Space Systems in Japan. On the other hand, there are no trainings in recent days for Directorate of Geology.

Table 3.36 List of Mines in Madagascar

No	Name of Mine	Proprietor (Ratio)	Location	Kind of Minerals	Mining Method	Period of Exploitation	Amount of Production (Products)		Environmental Issues	Issues of Mine Safety
1	Andriamana	Kraomita Malagasy S.A. [Government, (100)]	Ankazotaolana	Cr	OP	? -	0.25 Mt/y			
2	-	Kraomita Malagasy S.A. [Government, (100)]	Bemanevika	Cr	OP	?	0.20 Mt/y			
3	Ambatovy	Ambatovy Minerals S.A. [Sherritt International Corp., (40); Sumitomo Corp., (27.5); Korea Resources Corp., (27.5)]	Ambatovy	Ni, Co	OP	? -	0.60 Mt/y			
4	Mandena	QIT Madagascar Minerals SA [QIT Fer et Titane (a subsidiary of Rio Tinto plc) (80) Government, (20)]	Talagnao, Mandena	Ti, Zr	OP	-	0.75 Mt/y 0.015 Mt/y 0.025 Mt/y	ilmenite rutile zilcon		
5	Toamasina	Holcim S.A. [Holcim Group, (90)]	Toamasina	Ls	OP	-	0.30 Mt/y			
6	Ibity	Holcim (Madagascar) S.A. [Holcim Group, (90)]	Ibity	Ls	OP	-	0.16 Mt/y			
7	Ambohimanambola	Madagascar Long Cimenterie (Maloci)	Ambohimanamb ola	Ls	OP	-	0.36 Mt/y			
8	Artsrakambo	Etablissements Gallois S.A.	Near Brickaville	Grap	?	-	4800 t/y			
9	Marovinsty	Etablissements Gallois S.A.	Near Vatomandy	Grap	?	-	3600 t/y			
10	Ambalafotaka	Etablissements Gallois S.A.	?	Grap	?	-	? t/y			
11	Antsahampano	Compagnie Salinere de Madagascar	Antsahampano	Gypsum	?	-	500 t/y			
12	Tolagnaro	Societe des Mines d'Ampandranhava	Tolagnaro	Mica	?	-	2000 t/y	processe d		

3.8.4 Environmental Policy and State of Environment

Directorate of Mines and National Office of Environment are in charge of the management for mine environmental matters so far. Among these organization, the National Office of Environment has responsibility for approval work in respect of the EIA, which the National Office of Environment and the Directorate of Mines have conducted collaborative audit and monitoring for EIA and related inspection.

(1) Organization in Charge of Environment

Organization of environment related departments are shown in Figure 3.48. The National Office of Environment is comprised of Department of Environmental Assessment, Department of Quality and Communication and Department of Information.

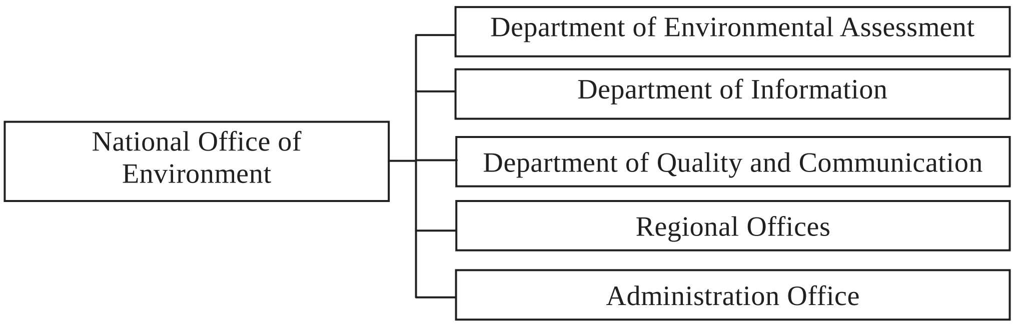


Figure 3.48 Organization chart of the Ministry of Environment, Water, Forest and Tourism

(2) Laws, etc. Relating to Environment

Legislations related to the environmental are as follows:
- Order of Adaptable Reservation for Investment Environment (MECIE): No. 167-2004 (2004)
- Regulation on the Environmental Conservation Areas: No. 4355/97 (1997)
- Order of Procedure on Environmental Impact Assessment: No. 6830/2001 (2001)
- Regulation on Forest Conservation Areas: No.18 732 (2004)
- On the temporary suppression of Mining and Forestry Permission within the Environmental Protection Areas: No. 19 560 (2004)
- Ministerial Order on the Control of Vehicle Exhaust Gas: No. 6941/2000 (2000)
- Ministerial Order on the Mining Sector and Environmental Protection: No. 12032/2000 (2000)
- Order of Resident Participation for Environmental Impact Assessment: No. 6830/2001 (2001)
- Regulation on the Drainage Water to Surface Water and Groundwater, etc.: No. 2003-943 (2003)
- Regulation on the Classification of Surface Water and Waste Water: No. 2003/464 (2003)
- Technical Guideline of Sectional Environmental Impact Assessment

Order of MECIE mentioned above is ranked as basic law, and other regulations are formulated depending on the MECIE.

In addition, regulation on the procedure of EIA and environmental contract, implementation of EIA, environmental evaluation, observance of monitoring, formulation of environmental technical order book on the environmental audit, etc. are presently examined.

(3) Process of Environmental Impact Assessment (EIA)

The process of EIA in Madagascar is shown in Figure 3.49.

(4) International Cooperation, etc.

There was a program for financing help by World Bank before 2009 as a support from overseas organization. However, there is no same kind of project for the ONE at the moment. As a training in recent days, one environment engineer was participated in remote sensing training at Japan Space Systems in Japan.

3.8.5 State of Mine Pollution and the Potential

(1) Mine Environment

There are no cases recognizing as mine pollution so far. On the other hand, outflow of soil at small-scale mine in the Manasavi area, where illegal miners has been digging alluvium Au, are concerned as a pollution potential site. Additionally, National Office of Environment has recognized that there is no original standards and the related laws in respect to mine environment should be revised to deal with current mining situation as a challenge for the government regulator side.

3.8.6 Mine Safety

There are no critical issues on the mine safety. However, there is a concern about lack of PPE for small-scale miners including illegal miners.

3.8.7 Present State of Human Resources Development and Request for Technical Training

(1) Present State of Human Resources Developing

There is no system concerning human resources development. Engineers are obtaining their skills via on the job training. There have been requests to participate in human resource development programs such as long-term training in Japan by JICA.

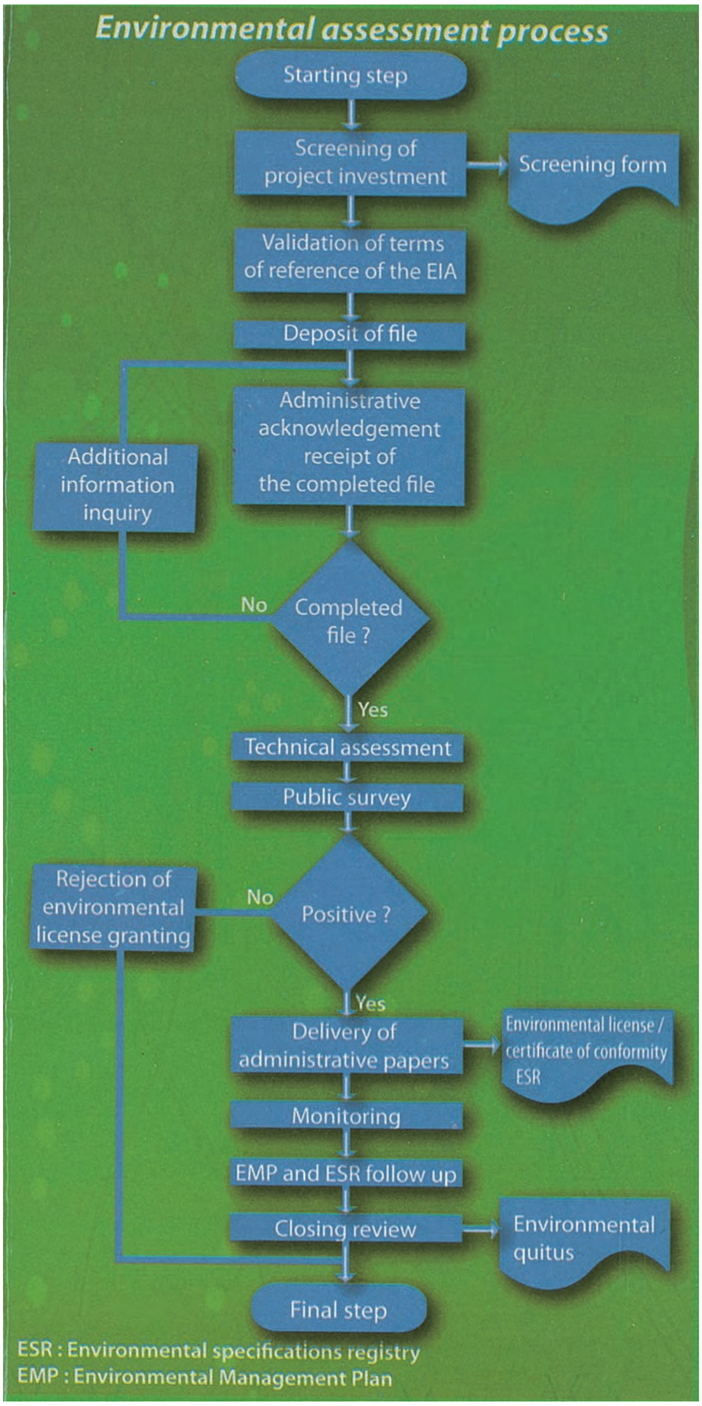


Figure 3.49 Environmental Impact Assessment process
(figure from leaflet of National Office of Environment)

(2) International Cooperation, etc.

There is no support for human resource development in respect of mining sector within recent from overseas organization. They have not participated in short-term trainings by JICA and JOGMEC. As training in recent, two engineers of Directorate of Mines and National Office of Environment were participated in remote sensing training at Japan Space Systems in Japan.

(3) Request on Technical Training in Japan

Related departments are highly interested in undertaking long-term training in Japan. The technical contents which they want to acquire are as follows,

(Directorate of Mines)

Technical items requested for:

- basic information relating to mine environment and technology for mining
- Request for support from JICA: upgrade of related laws and procedures, participation in the training for mining including site visit to several kind of mines, participation in the training of audit and management for mine environment and mine safety and support to enhance of mining technology and mine environmental management for Au mine hosted by JICA
- Training target person: all mining engineers in the department

(Directorate of Geology)

Technical items requested for:

- method for geological mapping and mineral resources exploration, method for geochemistry and ore assay, and technique for interpretation of satellite image and geophysical data
- Request for support from JICA: support to create geological map of scale 1:100,000, participation in the training for geological mapping and mineral exploration, participation in the training for interpretation of geophysical data, and support to set up of chemical laboratory hosted by JICA
- Training target person: all geologists in the department

(National Office of Environment)

Technical items requested for:

- methods for audit and monitoring of environment impact assessment including mining geological knowledge
- Request for support from JICA: participation in the short-term training for environmental management technique including mining geology knowledge hosted by JICA
- Training target person: all engineers (16 persons for Department of Environmental Assessment, 5 persons for Department of Quality and Communication, 8 persons for

Department of Information)

(University of Antananarivo)

Technical items requested for:

- methods for monitoring and management of mine environments such as discharged water, soil and air around mine area
- Request for support from JICA: Upgrading of infrastructures relating to the research, which items consist of vehicle for field survey, analysis equipment and upgrading of computer, software and internet environment

3.9 Summary of Mine Environment and Safety in the Southern Africa Area

3.9.1 Mine Management and Legislation related to the Mine Environment

Mine management and legislation related to the mine environment in the objective eight countries are shown in Table 3.37 (1) and (2).

Table 3.37 Mine Management and Legislation Related to the Mine Environment in the Objective Countries (1)

Objective Country	Ministries and Agencies in Charge			Legislation	Direction of Mining Policy
	Mine Management*1	Geology and Ore Deposit	Mine Environment	Mine Environment	
1. Angola	MGM: D. of Mine, Dep. of Mine Environment and Management	MGM: Geological Institute of Angola	MGM: D. of Mine, Dep. of Mine Environment and Management	-Mining Law (New) -Environment Act -EIA Act	- Mineral exploration and investment other than petroleum and diamond are being promoted under the new Mining Law. - New Mining Law is strongly involved to the mine environment and safety.
2. Zambia	MMEW: D. of Mine Development	MMEW: Geological Survey of Zambia	MMEW: D. of Mine Safety	-Mine and Mineral Development Act -Mining Regulation, etc. -Environmental Management Act -Regulation of EIA, etc.	-Main components of the mining policy consists of revision of decrees, creation of value-added, foundation of relevant infrastructure such as road, railway, water, energy, etc. and strengthening of mine environment and safety. -Establishment of environmental protection fund for the strengthening of environmental inspection and monitoring.
3. Malawi	Ministry of Mines: Dep. of Mining Inspection, Dep. of Mineral Promotion, Section of Policy and Planning	Ministry of Mines: Geological Survey of Malawi	Ministry of Mines: Dep. of Mining Inspection	-Law on Mines, Minerals and Resources -Nuclear Power Act -Environmental Management Act -Law on Safety, Health and Welfare, etc.	-Main components of mining policy consist of promotion of mineral resources development. -According the mining policy, the Mine and Mineral Act is being revised, and regulation related to the petroleum is also provided.
4. Botswana	MMEW: D. of Mines, Dep. of Mining Operation and Development	MMEW: Geological Survey of Botswana	MMEW: D. of Mines, Dep. of Mining Operation and Development	- Mining Law (New) -Regulation of Mine, Quarry and Machinery -Gunpowder Law and Regulation -Environmental Basic Law - EIA Act, etc.	-Mineral resources development except diamond is active. -Promoting foreign investment to the mining of diamond, Cu, Ni and coal. -Mine closure is regulated by the new Mining Law.
5. Zimbabwe	MMMD: D. of Mines	MMMD: D. of Geological Survey	MMMD: D. of Mine and Engineering	-Mines and Minerals Act	-
6. Mozambique	MMR: DG. of National Mines	MMR: DG. of National Geology, Institute of Geology	MMR: DG. of National Mines, Dep. of Environment	-Mining Law -Environmental Legislation Related to Mining Activity, Regulation on Mine Safety -Environmental Law, Environmental Quality, Environmental Standard for Discharging Waste Water, etc.	-After institution of revised Mining Law in 2002, the government aimed to interlock between promotion of natural resources development and economic growth. -At present, the development of coal mines have been active, and the contribution to the GDP due to mining sector will be increased to double. -Mining legislation is revised for well-defines.

*1: MGM: Ministry of Geology and Mines, MMEW: Ministry of Mines, Energy and Water Resources
MMMD: Ministry of Mine and Mining Development, MMR: Ministry of Mineral Resources, MEM: Ministry of Energy and Mines
DG.: Directorate General, D.: Directorate, Dep.: Department, EIA: Environmental Impact Assessment

Table 3.37 Mine Management and Legislation Related to the Mine Environment in the Objective Countries (2)

Objective Country	Ministries and Agencies in Charge			Legislation	Direction of Mining Policy
	Mine Management*1	Geology and Ore Deposit	Mine Environment	Mine Environment	
7. South Africa	MMR: Sector of Mineral Policy and Promotion, Sector of Mineral Legislation	Geological Survey of South Africa	MMR: Sector of Minerals, Welfare and Safety, Geological Survey of South Africa: Sector of Hydrogeology	-Law on Mineral and Petroleum Resources Development -Environmental Protection Law -Environmental Management Law -Law on Water Use, etc.	-Main components of mining policy consists of mining safety, revision of BEE policy established by the Mining Charter, examination of possibility of establishment of national enterprises, etc. -Commence of added value strategy on mineral resources, such as Au, PGM, Ni, Fe, Cr, etc., and examination of installation of carbon tax.
8. Madagascar	MOM: Dep. of Mines	MEM: Dep. of Geology	MEM Dep. of Mines	-Mining Law (New) -Mining Regulation (New) -Large Investment Law	- There is not definite movement related to the mining policy due to the political instability after 2009. -However, the mining development on Ni Ti, etc. is going on at present.

*1: MGM: Ministry of Geology and Mines, MMEW: Ministry of Mines, Energy and Water Resources
MMMD: Ministry of Mine and Mining Development, MMR: Ministry of Mineral Resources, MEM: Ministry of Energy and Mines
DG.: Directorate General, D.: Directorate, Dep.: Department, EIA: Environmental Impact Assessment

Each country has newly instituted or revised the laws in 1990's to 2000's in order to promote mining development as well as a sustainable development of mineral exploration and exploitation of minerals. And then, mining policies were shifted from mining depending on only specific minerals such as Au, diamond, etc. to the mineral exploration and exploitation of various kinds of mineral resources such as base metals, rare earth elements (REE) and energy resources (petroleum, natural gas and coal).

However, several countries and areas still have problems of infrastructure building for the mine development and difficulties to promote foreign investment for mineral exploration and exploitation.

3.9.2 Mining Condition

Mining condition and potential of mineral resources in the 8 objective countries are shown in Table 3.38 (1), (2) and (3).

Table 3.38Mining Condition and Potential of Mineral Resources in the Objective Countries (1)

Objective Country	Operating Mines*1, Ore*2: Number of Mines	Closed mines Ore: Number of Mines	Smelter / Refinery	Potential of Mineral Resources	Mining Condition
1. Angola	Dia: 11 LS: 2 Gp: 1	Fe: 1 Cu: 1	-	Nb, Ta, REE, Cu, Co, Ni, Fe, K, S, P, Fluorite, Barite, etc.	-Redevelopment of closed mines (Fe, Au) and newly development mines (Cu, Co, Ni, Au, P) are going on along the southwestern extension area of existing copper belt.

*1: Exception of petroleum and natural gas.
*2: Dia: Diamond, LS: Cement, Gp: Gypsum, Grap: Graphite, PGM: Platinum group, Py: Pyrite, REE: Rare Earth.

Table 3.38Mining Condition and Potential of Mineral Resources in the Objective Countries (2)

Objective Country	Operating Mines*1, Ore*2: Number of Mines	Closed mines Ore: Number of Mines	Smelter / Refinery	Potential of Mineral Resources	Mining Condition
2. Zambia	Cu, Co: 8 Cu, Au: 1 Cu, Co, U, Au: 1 Cu: 1 Ni, Co, Cu: 1 Ni, Co, Cu, Pt: 1 Py: 1 LS: 3 Coal: 2	Pb, Zn: 1	Cu: 9 Cu, Co: 3 Co: 1	Cu, Co, Zn, Pb, Au, Mn, U, V, Ni, etc.	-Operating mines are concentrated along the copper belt. Main mineral components mainly consist of Cu and Co. -Objective minerals of current mineral exploration and developing mines at the F/S stage also consist of Cu and Co.
3. Malawi	U: 1 LS: 1 Ps: 1 Coal: 3 Rock material: 2 Gemstone: 2	-	-	Nb, Ta, La, U, Zr, etc.	-Mineral exploration of rare metals and REE is activating in the country. -Presently, operating mines are only uranium.
4. Botswana	Dia: 5 Ni, Cu, Co: 3 Au: 1 Cu: 1 Clay: 2 Coal: 1	Mn: 1 Au: ?	Ni, Cu, Co: 1	Dia, Cu, Ni	- Mineral exploration is intensely carried out along the southwestern extension area of existing copper belt. A few copper mines have been developed in the area.
5. Zimbabwe	Dia: 3 Pt（Ni）: 2 PGM: 2 Ni: 4 Asb: 2 Cr: 4 Co: 4 Au: 17 Cu: 4 Fe: 1 Li: 1 P: 1 Py: 1 Vm: 2 Coal: 4	-	Ni: 2 Cu: 1 Fe: 3 PGM: 3	Cr, Au, Coal, etc.	-Main mining policy consists of sustainable development of mines and creation of jobs for more workers.
6. Mozambique	Au: 1 Ta: 2 Al: 1 Ti, Zr: 1 LS: 4 Coal: 2 Grap: 1 Diatomite: 1 Clay (Bentonite): 1 Gemstone: 8	-	Al: 1	Au, Ti, Ta, REE, U, Coal, Petroleum, Gas, etc.	-Important minerals for the mining sector is presently coal in the country, thus coal mines at the stage of F/S or waiting for development are about 10 developing projects in the Tete Province. -There are many project of mineral exploration stage concerning the Au and REE in the country.

*1: Exception of petroleum and natural gas.
*2: Dia: Diamond, LS: Cement, Gp: Gypsum, Grap: Graphite, PGM: Platinum group, Py: Pyrite, REE: Rare Earth.

Table 3.38Mining Condition and Potential of Mineral Resources in the Objective Countries (3)

Objective Country	Operating Mines*1, Ore*2: Number of Mines	Closed mines Ore: Number of Mines	Smelter / Refinery	Potential of Mineral Resources	Mining Condition
7. South Africa	Ni: 64 Au: 44 PGM: 28 Cr: 27 Dia: 14 Cu: 15 Pb: 1 Zn: 1 Mn: 6 W: 1 V: 3 U: 2 Ti: 3 Zr: 5 P: 1 Sb: 1 Coal: 53 Fluorite: 3 Pyrophillite: 3 Vm: 3 Rock material: 2	Au, > 5,000	Ni: 3 Au: 1 PGM: 4 Cu: 8 Zn: 1 Ti: 4 Zr: 1 Al: 1	PGM, Au, Cr, Ni, Cu, U, Coal, etc.	-There are more than 50 projects concerning PGM, Au, coal, etc. of developing or F/S stages. -Although the mining sector is still active, the problems of mine environment and labor difficulties exist.
8. Madagascar	Cr: 2 Ni,Co: 1 Ti, Zn: 1 LS: 3 Grap: 3 Gypsum: 1 Mica : 1	-	Ni:1	Au, Ni, Co, Cu, Pb, Zn, PGM, Al, U, Coal, Petroleum, etc.	-Maintenance of infrastructure is backward, thus the mining development is delayed. -Political unstablility.

*1: Exception of petroleum and natural gas.
*2: Dia: Diamond, LS: Cement, Gp: Gypsum, Grap: Graphite, PGM: Platinum group, Py: Pyrite, REE: Rare Earth.

In South Africa, Zimbabwe and Zambia, various kinds of mineral resources has been historically developed for a long time. In other countries, the development of mineral resources was relatively recent and further mineral exploration and mine development are expected because of high potential of mineral resources.

Particularly, active mineral exploration and a few copper mines have been developed in the southwestward extension areas from the Copper Belt, located along the boundary between Zambia and Democratic Republic of the Congo, in Angola and Botswana (called as Kalahari Copper Belt).

3.9.3 Environmental Policy and Environmental Condition

Environmental services, environmental impact assessment (EIA) and environmental condition in the objective countries are shown in Table 3.39 (1) and (2).

Table 3.39 Environmental Services, EIA and Environmental Condition (1)

Objective Country	Ministries and Agencies in Charge			Environmental Legislation	Environmental Policy, etc.
	Environmental Management	Environmental Permit (EIA*1)	Environmental Inspection		
1. Angola	MoE: D. of Protection and EIA	MoE: D. of Protection and EIA	MoE: D. of Protection and EIA	-Environmental Law -National Park Act -Environmental Protection Act -Waste Management Act, etc.	-Various environmental standards are installed. -Environmental protection, mine closure, compensation, etc. as an environmental consideration are formulated by the Mining Law.
2. Zambia	MLNREP: Environmental Management Agency	MLNREP: Environmental Management Agency	MLNREP: Environmental Management Agency. Dep. of Inspection	-Environmental Management Act. -Degree of Harmful waste Management -Degree of EIA -Degree for Air Pollution Control. -Degree for Water Environment Protection.	- Formulation of Environment Support Program at the same time installation of Environmental Protection and Pollution Control Act in 1990. After that, environmental policy is continued.
3. Malawi	MECCM: D. of Environment	MECCM: D. of Environment	MECCM: D. of Environment, Section of EIA and Inspection	- Environmental Management Act. -Policy of Environmental Management, etc.	- Environmental Management Act includes the basic orders concerning the water, air, soil, waste, etc. -There are not guidelines, manuals, etc.
4. Botswana	MEWT: D. of Environment	MEWT: D. of Environment	MEWT: D. of Environment, D. of Waste Management	-EIA Act. -Air Pollution Control Act. -Water Contamination Control Act. -Noise Pollution Control Act. -Various Environmental Standards, etc.	-Most of environmental legislation has been installed. -Public pollutions have charged of the Directorate of Waste Management.
5. Zimbabwe	MEWM: Dep. of Environmental Affairs	MEWM: Environmental Management Agency	MEWM: Environmental Management Agency	-Environmental Management Act. -EIA Policy. -National Environmental Hawser -National Park and Wildlife Protection Act. -Water Act. -Forest Act. - Various Environmental Standards, etc.	- Department of Environmental Affairs is in charge of formulation of environmental policy, Environmental Management Agency is in charge of enforcement organization of its policy. -Basic policy of environment is aiming for the sustainable development.
6. Mozam-bique	MoE: DG.. of National EIA	MoE: DG.. of National EIA	MoE: DG.. of National EIA	-Environmental Law. -Environmental Quality Standards. -Effluent Standard -Drinking Water Standard, etc.	-Guidelines and manuals for the environmental regulation are not set up yet; however those guidelines, etc. are ongoing to set up in support of World Bank. - Environmental Management Act includes the basic orders concerning the water, air, soil, waste, etc.
7. South Africa	MoE: DG. of Internal Inspection Ministry of Water	MoE: DG. of Internal Inspection	MoE: DG. of Internal Inspection Ministry of Water	-Environmental Protection Act. -Environmental Management Act. -Law on Water Use, etc.	-Environment related to the acidic mine water occurs much problem. -Environmental management and monitoring works are much active.

Table 3.39 Environmental Services, EIA and Environmental Condition (2)

Objective Country	Ministries and Agencies in Charge			Environmental Legislation	Environmental Policy, etc.
	Environmental Management	Environmental Permit (EIA*1)	Environmental Inspection		
8. Madagascar	ONE:Dep.of Environmental Assessment,Dep.of Environmental Assessment,Dep.of Information,Dep.of Qualityand Communication	ONE:Dep.of Environmental Assessment,Dep.of Environmental Assessment,Dep.of Information,Dep.of Qualityand Communication	ONE:Dep.of Environmental Assessment,Dep.of Environmental Assessment,Dep.of Information,Dep.of Qualityand Communication	-Order of Adaptable Reservation for Investment Environment -Regulation on the Environmental Conservation Areas, etc.	-Audit and minitoring work are implementing , however, there are no original standards so far.

The environmental legislation, including Environmental (Basic) Law, Environmental Protection Act, etc., is mostly instituted in each country. The environmental impact assessment is mostly regulated within the Environmental (Basic) Law, and the Ministry of Environment is enforced to formulate the environmental policy. The evaluation of environmental impact assessment concerning mineral exploration and exploitation in the Ministry of Environment of the objective countries are entrusted to the ministry in charge of mining. However, staff in charge of environmental evaluation concerning the mining in each country lack practical experiences, therefore it is necessary to formulate and enforce a long-term personnel training.

Concerning the environmental protection such as an environmental management and monitoring plans, project enforcement person in most of countries the responsibility to carry out the environmental obligation according to the Mining Law. However, monitoring enforcement system in whole area of each country is not built yet, thus environmental condition including environmental pollution, hot spots, etc. in each objective country is not comprehended yet.

Environmental standards for air quality, water quality, soil quality, noise and vibration, etc. had mostly set up in objective countries; however a few environmental items are not set up in some countries. Therefore, it is necessary fully to install the environmental standards for the environmental evaluation.

3.9.4 Mine Pollution, its Potential and Measures

Mine pollution, its potential and measures in the 8 objective countries are shown in Table 3.40.

Table 3.40 Mine Pollution, its Potential and Measures in the Objective Countries

Objective Country	Mine Pollution / Potential of Mine Pollution (Classification*1)			Environmental Measures, etc.	Remarks
	Name of Mine	Ore	Condition		
1. Angola	-	-	-	-	
2. Zambia	(Mine pollution) 1) Konkola Mine 2) Mufulira Mine 3) Lumwana Mine 4) Chambishi Cu Smelter 5) Kabwe Mine	 Cu, Co Cu, Co Cu, Co Cu Pb, Zn	 -Wastewater, exhaust gas -Wastewater, exhaust gas -Wastewater -Exhaust gas -Tailings dam, exhaust gas	 - - - - -	-Environmental Management Agency had ordered the environmental measures to the mine in 2013. -The mine site was designated as mine pollution by the environmental organization. - Environmental Management Agency had ordered to close mine to the mine in 2013. - The mine site was designated as serious polluted site by the environmental organization. - Environmental Management Agency had ordered to stop a part of development to the mine in 2013.
	(Potential of mine pollution) 1) Luanshya Mine 2) Chambishi Mine 3) Kansanshi Mine 4) Munali Mine 5) Chambishi Smelter 6) Chambishi Refinary	 Cu, Co Cu, Co Cu, Co, Ni Cu Cu Co	 -Wastewater, exhaust gas -Wastewater, exhaust gas -Wastewater, exhaust gas, -Wastewater, exhaust gas - - Exhaust gas	 - - - - - -	
3. Malawi	(Potential of mine pollution) 1) Kayelekera Mine 2) Mchenga Mine 3) Terrastone Mine	 U Coal Aggregate	 -Dust, tailings -Dust, exhaust gas -Tailings	 - - -	
4. Botswana	・Selebi-Phikwe Mine & Smelter ・Tati Mine ・Mupane Mine	Ni, Cu, Co Ni, Cu, Co Au	-Wastewater, exhaust gas, quarry of sand - -Wastewater including cyanide	-Air pollution - -Influence to ecosystem	
5. Zimbabwe	(Potential of mine pollution) 1） Mashoraland Central Area 2) Mashoraland west Area 3) Midland Area 4) Miat South Area	-	-	-	
6. Mozam-bique	(Potential of mine pollution) 1) SSM in the Manica Province, etc. 2) Mavuzi Mine (closed)	 Au U	 - Wastewater, tailings - Tailings	 - -In operation of off-limit	-There is mine pollution of Hg due to illegal mining.
7. South Africa	(Potential of mine pollution) 1) Wit watersrand gold mine basin 2) Au mine area of Kosh, etc. 3) Bushvelt PGMZone 4) Miterburg coal mine Area	 Au Au PGM, Cu Coal	 -Wastewater, tailings - Wastewater, tailings - Wastewater - Wastewater, tailings	 - -In operation of monitoring -In operation of monitoring -In operation of monitoring	-The measuring method had been applied with EIA. -Storage water for drinking was polluted by mine water in 2012.
8. Madagascar	(Potential of mine pollution) ・Small-scal mines in Manasavi area	Au(Alluvium)	-flowout of soil and river pollution	-unk.	

*1 : Classification: Mine pollution, Potential of mine pollution
Abbreviations: SSM: Small-scaled mining

Mine development of sulfide ore deposits such as base metals is rare in Angola, Malawi and Mozambique, therefore ore pollution is presently not found in these areas. However, those areas have also potential of mine pollution.

Other countries has been found to have mine pollutions such as acidic wastewater from mine sites, exhaust gas from smelters, etc. and much influence to the environment downwards. The environmental investigation and mitigation against the mine pollution is inefficient. It is necessary to carry out environmental investigation by monitoring for understanding the environmental condition and formulate the technical guidelines, etc. for counter measures and enforcement.

3.9.5 Mine Safety

The conditions of safety in the 8 objective countries are shown in Table 3.41 (1) and (2).

Table 3.41 Condition of Safety in the Objective Countries (1)

Objective Country	Mine Safety		Occurrence of Accidents and Disease, etc.	Measures for Safety, etc.	Remarks
	Management Office	Relevant Legislation			
1. Angola	MMMD: D. of Mines, Dep. of Mines Environmental Management	-Regulating by new Mining law.	- No accidents and diseases in mine sites. However, accidents occur in petroleum sites.	-	-Preparation of Mining Law.
2. Zambia	MMEW: D. of Mine Safety	- Regulating by Mine and Mineral Development Act. -Order of Gunpowder	- Roof fall, small earthquake in underground, collapse of tailings dam, electric failure, working trouble, etc. -Nchanga Mine: More than 200 people were locked in underground due to electric failure in 2011.	-Warning. -Buck-up system for electric failure.	-
3. Malawi	MoM: Dep. of Mine Inspection, MLVT: D. of Vocation, Safety and Sanitary	- Regulating by Mine and Mineral Act and its measures. -Safety, Health and Welfare Act. -Nuclear Act -Gunpowder Act	-Mchenga Coal Mine: Rock-fall and fall of rock fragment in vertical shaft. -Quarry: Accident by dynamite explosion and falloff rock fragment at quarry site.	-Inspection and warning.	-Examination of influence of radioactive to human health at the uranium mine site.
4. Botswana	MMEW: D. of Mines, Mining Operation and Development	- Regulating by new Mining law.	-Year 2012: Accident: 36 cases (fatal case: 4 cases) -Year 2013 (～October): Accident: 24 cases (fatal case: 3 cases)	- Warning. -Inspection for illegal mining (Au, etc.).	-Regulating safety by the Mining Law.
5. Zimbabwe	-		-Year 2010: Accident: 36 cases (fatal case: 40.cases) -Year 2011: Accident: 30 cases (fatal case: 37.cases) due to roof fall, fall at shaft, eruption of gas, etc.	- Warning. -Safety training by the Chamber of Mines (COM).	-Release of statistic concerning the safety and safety training by COM.
6. Mozam-bique	MMR: DG. of National Mines, Dep. of Mine Safety	-Order of Mine and Safety.	-Fatal cases due to rock fall, blasting, etc. at SSM. -Year 2010: Moma Ti-Zr Mine: Fatal case at tailings dam Broken.	- Inspection and Warning.	-Revising plan of relevant mining and safety acts.

*1: MLVT: Ministry of Labor and Vocational Training, MMR: Ministry of Mineral Resources,

Table 3.41 Condition of Safety in the Objective Countries (2)

Objective Country	Mine Safety		Occurrence of Accidents and Disease, etc.	Measures for Safety, etc.	Remarks
	Management Office	Relevant Legislation			
7. South Africa	MMR: Sector of Mineral, Sanitary and Safety	-Mine Safety and Health Act.	-There are so many cases and fatal cases due to rock fall, roof fall, etc. -Year 2007: Several thousand workers had been Blocked in underground at Elandsrand Au Minein 2007. -Tau Tona Au Mine: Many cases of roof falls in this mine. -Total fatal cases in South Africa: Some 100 cases, number of accident: several thousand cases. -There were many fatal cases of strike associated with riot and gunfire for negotiations for a wage increase.	- Inspection and Warning.	-Strong warning on mine safety to miners.
8. Madagascar	MoM: Dep.of Mines	-Mining Law (New) -Mining Regulation (New)	-	-	

*1: MLVT: Ministry of Labor and Vocational Training, MMR: Ministry of Mineral Resources,

Statistic on disaster and accident in mines and smelters has been obtained in Botswana and Zimbabwe, but those of other countries was not obtained.

Concerning mine safety, ministry and government agency in charge in each country are supervising operating mines such as ministerial direction, order, etc. without practical training for the mine safety. However, technical training of mine safety is periodically enforced by the Chamber of Mines in Zimbabwe.

3.9.6 Personnel Training and Requests of Technical Training

Personnel training and requests of technical training in the 8 objective countries are shown in Table 3.42 (1) and (2).

Table 3.42 Personnel Training and Requests of Technical Training in the Objective Countries (1)

Objective Country	Personnel Training	Request of Technical Training (by category)	History of International Cooperation, etc.
1. Angola	-MGM: None.	-D. of Mines: GIS, calculation of reserves, mining, mine safety. -Geological Institute: Chemical analysis and management, geophysical and geochemical exploration, hydrogeology, mineral exploration, EIA. -MoE: EIA method.	-France: BRGM. -Japan: technical training by JICA and JOGMEC.
2. Zambia	-MMEW (Geological Survey of Zambia) : Technical training provided by JICA and JOGMEC. -Other ministries: None. -Environmental Management Agency: None.	-D. of Mine Development: New technology on mining, mine management method. -D. of Mine Safety: mine environment (wastewater, soil, air, etc.), monitoring, and management method.	-World Bank: Administrative assist (Environment). - Japan: technical training by JICA and JOGMEC.

Table 3.42　Personnel Training and Requests of Technical Training in the Objective Countries (2)

Objective Country	Personnel Training	Request of Technical Training (by category)	History of International Cooperation, etc.
2. Zambia	-MMEW (Geological Survey of Zambia) : Technical training provided by JICA and JOGMEC. -Other ministries: None. -Environmental Management Agency: None.	-Environmental Management Agency: Monitoring for air quality, management method, management of closed mines, management on wastewater in mine site, monitoring method for air quality around mine site, monitoring method for radioactive, evaluation method on EIA. -Geological Survey: Mineral exploration method, mine environmental survey method based on hydrogeology.	-World Bank: Administrative assist (Environment). - Japan: technical training by JICA and JOGMEC.
3. Malawi	-MoM (except Geological Survey of Malawi): Training in Australia. -MECCM: None. -MLVT: None.	-D. of Mines: Mine management, inspection and monitoring technology including mine environment and safety, inspection of EIA and monitoring technology. -D. of Environment: Inspection for mine environment, EIA and monitoring technology. - D. of Vocation, Safety and health: Inspection for mine safety and monitoring technology.	-Australia: Technical training (Mine safety). -World Bank, EU（BRGM）: Assistance of mineral exploration (Air bone). - Japan: technical training by JICA and JOGMEC.
4. Botswana	-MMEW: None. -MEWT: Technical training by JICA. -Geological Survey of Botswana: Technical training by JOGMEC.	-MMEW: Mine environment and safety, management for reserves, and mining policy. -MEWT: Environmental management, EIA, environmental legislation, monitoring, SEIA, evaluation method of EIA. -Geological Survey: Groundwater, CCS, sustainable mine development, monitoring, petroleum development, geochemical exploration, applied environmental geology, petroleum geology, and hydrochemistry.	-German: Technical training (Environmental geology, analysis, etc.) -JICA: Technical training. - Japan: technical training by JOGMEC.
5. Zimbabwe	-MEWT, Environmental Management Agency, Laboratory: Technical training by JICA.	-MEWT, Dep. of Environmental Affairs and Environmental Management Agency: Environmental policy, environmental planning, environmental management.	-
6. Mozam-bique	-MMR (except DG. Of National Geology): None. -MMR (DG. Of National Geology): Technical training by JICA, JOGMEC, HIDA, Australia, India, etc. -MoE: Technical training by JICA and JOGMEC.	-DG. of National Mine, D. of Environment: EIA related to mine environment, environmental management system, hydrogeological monitoring inspection method, remote sensing on mine environment and analysis of GIS. -DG. Of National EIA: Inspection on EIA related to mine environment and monitoring technology. -DG. Of National Geology: Geophysics (seismology), structural geology, and mineralogy.	-Australia: Technical training (Mineral resources). -India: Technical training (Coal resources). -World Bank with Poland: Technical assistance (Formulation of technical guidelines) - Japan: technical training by JICA and JOGMEC.
7. South Africa	-Geological Survey of South Africa: None.	-Geological Survey, Sector of Hydrogeology: Hydrogeological technology related to mine environment.	-Ministry of Water: Assistances on wastewater and water treatment method from several countries and UN. -Geological Survey, Sector of Hydrogeology: None.
8. Madagascar	-MoM (Dep.of Mines): None. -MoM (Dep.of Geology): None. -ONE (Departments): None.	-Dep.of Mines: Upgrade of related laws -Dep.of Geology:Suppot to create Reginal Geological Map -ONE: Support to training for technique of EIA audit and monitoring	-Dept.of Geology: Budget assist from World Bank, development support from JICA -ONE: Budget assist from World Bank

Chapter 4 Second Site Investigation

4.1 Details of the Second Site Investigation

Second site investigation was conducted in the two objective countries through site visit and follow-up of the first site investigation was carried out in several countries.

The second site investigation was done in Malawi and Zambia. The investigation comprised of 1) environmental investigation, 2) soil sampling and analysis, 3) water sampling and analysis, 4) simple survey, 5) investigation of pollution; site of occurrence, scale and details of the pollution, environmental condition around the pollution, organizing related information and issues, consideration of prevention of mine pollution, collecting information about mine environment and safety, and so on.

The objective countries for the follow-up investigation of the first site investigation covered three countries, including, Zimbabwe, South Africa and Madagascar, and for this the study team divided into two groups during the visit.

4.2 Objective Sites for the Site Investigation

Overview of objective sites of the second site investigation is shown in Table 4.1 and Figure 2.2 (Chapter 2).

Table 4.1 (1) Objective Sites of the Second Site Investigation

Country	Investigation Site		Time Period	Remarks
	Site	Purpose		
1. Malawi	1) Coal mine	- Mine safety - Mine environment	Jan./20 - Jan./26	-
	2) Coal mine	- Mine safety - Mine environment		
	3) Small-scale mine (SSM)	- Mine safety - Mine environment		
2. Zambia	1) Konkola Mine (Cu): Konkola Copper Mines plc (Vedanta Resources plc (79.4%), ZCCM (20.6%))	- Drainage water - Flue gas*1	Jan./27 - Feb./16	- The site investi-gation at the objective mine needs to be gotten permission to enter the mine area from the mine owners. However, the permission will be obtained due to ZCCM has shares of the mine.
	2) Mufulira Mine (Cu): Mopani Copper Mines (Glencore Interna- tional AG	- Drainage water - Flue gas*1		
	3) Kabwe 鉱山 (Cu): ZCCM (100%)	- Drainage water - Slag dump		

*1 Flue Gas: flue gas from smelter including SO_2

Table 4.1 (2) Objective Sites of the Second Site Investigation

Country	Investigation Site: Object government and agency	Investigation Site: Contents of collecting information	Time Period	Remarks
3. Zimbabwe : Group 1	1) Ministry of Mines and Mining Development / Mining Development Authority	- Mine management - Mine environment, mine pollution, potential and the prevention method - Mine safety, incident, disaster and the prevention method - Analysis and monitoring - Human resource development and request	Jan./17 - Jan./21	- need a permission with secretary for the collecting on ahead
4. South Africa : Group 2	1) Department of Mineral Resources	- Mine management - Mine environment, mine pollution, potential and the prevention method - Mine safety, incident, disaster and the prevention method - Analysis and monitoring - Human resource development and request	Feb./17 - Feb./21	- need a permission with secretary for the collecting on ahead
5. Madagascar : Group 2	1) Department of Mines, Ministry of Mines	- Mine management - Mine environment, mine pollution, potential and the prevention method - Mine safety, incident, disaster and the prevention method - Analysis and monitoring - Human resource development and request	Feb./22 - Feb./28	- collection of the questionnaire - need a permission with secretary for the collecting on ahead
	2) Department of Geology, Ministry of Mines	- Current situation about geology, ore deposit and exploration - Analysis and monitoring - Human resource development and request		
	3) National Office of Environment	- Environmental management - Environment impact assessment (EIA) - Environmental conservation, environmental and mine pollution and the prevention - Waste management - Analysis and monitoring - Human resource development and request		

4.3 Malawi

Second investigation in the Malawi was conducted during 19th January to 28th January on 2014.

4.3.1 Schedule

Schedule is shown in Table 4.2.

Table 4.2 Schedule for Second Investigation in Malawi

No	Month/ Day	Time	Place	Item of Work	Persons met
1	Jan./19 (Sun)	-	Into Malawi	Traveling	-
2	Jan./20 (Mon.)	 9:00 - 11:00 - 13:00 -	Lilongwe: JICA Office Department of Mines Environmental Affairs Department	 Meeting on investigation Arrangement for investigation Meeting and interview.	 Assistant Representative and other related staffs Principal mining engineers JICA Expert and principal engineer
3	Jan./21 (Tue)	 9:00 - 16:00 -	Lilongwe: Department of Mines To Mzuzu Northern Office of Department of Mines	 Courtesy and meeting on investigation. Traveling Meeting for investigation	 Director General manager of the Office
4	Jan./22 (Wed)	 9:30 - 15:00 -	Mchenga: Mchenga coal mine Jalawe coal mine	 Inspection Inspection	 Mine manager Workers
5	Jan./23 (Thu)	 10:30 -	Livingstonia: Kaziwiziwi coal mine	 Inspection	 Mine manager
6	Jan./24 (Fri)	 9:30 - 10:30 - 12:00 - 13:00 -	Mzimba: Mzimba Gemstone Cooperative Society Changwue gem mine Muzumwanda gem mine Mzimba Gemstone Cooperative Society	 Investigation Investigation Investigation Hearing and discussion	 Owners Owners Owners Owners
7	Jan.25 (Sat)	-	To Lilongwe	Traveling	-
8	Jan.26 (Sun)	-	Lilongwe:	Arrangement of information	-
9	Jan.27 (Mon)	 9:00 - 10:00 - 11:00 -	Lilongwe: Department of Mines JICA Office JICA OVOP Office	 Report on outlines of site visit. Report on outlines of site visit.	 Director and senior engineer Assistant Representative and other related staffs Principal advisor
10	Jan.28 (Tue)	-	To Zambia	Traveling	-

4.3.2 Brief Investigation Summary

Sites are comprised of three coal mines at north of Rumphi and two gem mines at around of Muzimba, these sites located in the northern part of Malawi.

Location and brief overview of the site investigation are shown in Figure 4.1 and Table 4.3.

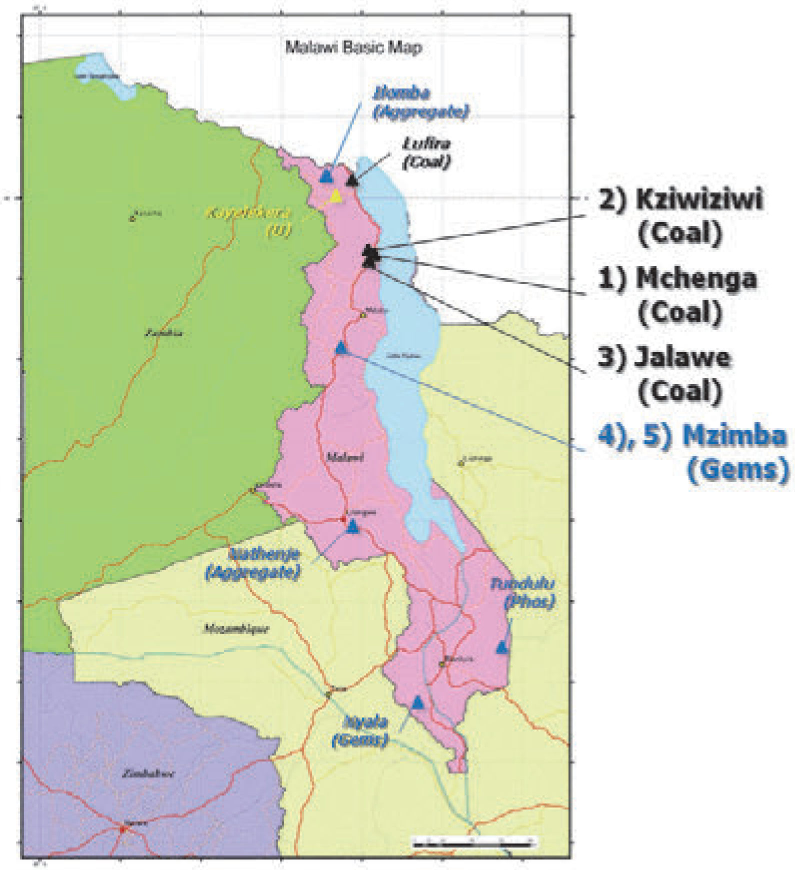


Figure 4.1 Objective Site Locations in Malawi

Table 4.3 Brief Overview of the Investigation Site

Site Name		Lat. (deg S)	Lon. (deg E)	Owner	Operation Method*1	Production	Remarks
1)	Mchenga Coal Mine	10.69907	34.14920	Muchenga Coal Mines Ltd.	UG	60-80t/day	Goverment had held before 1999.
2)	Kaziwiziwi coal mine	10.64587	34.09185	Kaziwiziwi Mining Company Ltd.	UG	60-70t/day	Goverment had operated durring 1985 to 2002.
3)	Jalawe Coal Mine (small scale)	10.74434	34.13648	Malawian	UG	12-30t/day	Opend in 2005
4)	Changwue gem mine (small scale)	11.84644	33.65318	Mzimba Gemstone	OP	n/d (mica, quartz, aquamrine)	Opend in around 2007
5)	Muzumwanda gem mine (small scale)	12.03776	33.65154	Mzimba Gemstone	OP	n/d (mica, rose quartz, aquamrine)	n/d

*[1] UG: underground, OP: open-pit

View details of the site investigation are comprised of situations at drainage and management relating to mining activities which consist of mining, coal cleaning, coal stocking and slug dumping. Additionally, view details in respect to mine safety are comprised of wearing of PPE, installation and management conditions of fence and pillar at undergrounds and open spaces. Simple analyses at drainages and streams around these mines are conducted as an investigation method for determination of mine environment.

4.3.3 Investigation for Mine Environment

Summaries for each site are as follows;

(1) Mchenga coal mine (Photo 4.1 and 4.2)

- Mining method: Underground
- Condition of drainage treatment: The discharged water from underground is not much and is not conducted by pumping machine.
- Condition of coal and rock waste dumps: Coal and rock waste are piling on the dumps around the mine mouth and washing plant. The amount of waste (sandstone) is very less.
- Management condition of discharged water, coal and rock waste dumps: The discharged water from underground is not much. However, discharge water and small ponds, which were generated by penetration of rain water, exist in the coal stock yard. These waters basically flow into peripheral stream and stone bonds as a filter are set up between spilway from the mine mouth and the stream (Photo 4.3 and 4.4).
- Others: Out flow of waste water from the abandoned pit and subsidences and collapses on the surface are observed near the mine mouth. These are left in current situation and the wastewater flows out to the stream directly (Photo 4.5).
- Measurement of element for the waters: These mine water from mine mouth and facilities was sampled by portable equipments (Photo 4.6). The water quality is shown in Table 4.4. Wastewater of abandoned pit has a characteristic of acid water such as pH 3.01. On the other hand, the some other sites show over pH 7.0. Content of acid water from the abandoned pit showed over 5mg/l in total metals and over 2mg/l in zinc.

Photo 4.1 Situation of Pit Mouth of the Mchenga Coal Mine

Photo 4.2 Mouth of Drift at Mchenga Coal Mine

Photo 4.3 Condition of Drainage Water from Stock of Crude Ore at the Mouth

Photo 4.4 Drainage Filter by Stone Bond under the Crude Stock

Photo 4.5 Outflow of Drainage Water from Former Mine Mouth and Collapse of the Upper Portion of the Mouth

Photo 4.6 Simple Analysis for Water Quality Together with Related Engineers

(2) Kaziwiziwi coal mine (Photo 4.7 and 4.8)

- Mining method: Underground
- Condition of drainage treatment: The discharged water from underground is less and is not conducted by pumping machine (Photo 4.9).
- Condition of coal and rock waste dumps: Coal and rock waste are piling on the dumps around the mine mouth and washing plant. The amount of waste (sandstone) is not much. A part of the coal yard contacts with river.
- Management condition of discharged water, coal and rock waste dumps: The discharged water from underground is not substantial. However, some water exist in coal cleaning and washing plants in which the water generated as discharged water by penetration of rainwater. These waters basically flow into peripheral stream and sediment ponds that are set up at 100m downstream from the plants (Photo 4.10).

- Others: Waste water in the sediment pond overflows due to heavy rain.
- Measurement of element for the waters: The pH value of the discharged water at coal washing plant shows over 6.0.

Photo 4.7 Mine Entrance of Kaziwiziwi Coal Mine

Photo 4.8 Administration Office of the Kaziwiziwi Coal Mine

Photo 4.9 Condition of Mine Mouth

Photo 4.10 Drainage Water and Slag Sump from Washing Plant

(3) Jalawe coal mine (Small-scale mine)

- Mining method: Underground (Photo 4.11)
- Condition of drainage treatment: The discharged water from underground is not much, however a pumping machine is occasionally used for draining.
- Condition of coal and rock waste dumps: Coal and rock waste are piling on the dumps around the mine office (Photo 4.12). The amount of waste (sandstone) is very less. A part of the coal yard contacts with stream.
- Management condition of discharged water, coal and rock waste dumps: The discharged water from underground is directly flowing into a stream. Additionally, coal stocks piles beside the

stream as well. For such situations, these discharged waters are not managed by the owner.

- Others: There are many mine mouths which exist as traces of illegal mining (Photo 4.13). Discharged waters from the mouths flow directly into the stream during heavy rainfall.

Photo 4.11 Condition of Mine Mouth of Jalawe Coal Mine (small-scale)

Photo 4.12 Mine Office and Stock Pile

Photo 4.13 Former Pit Mouth (there are several mouth along the stream)

Photo 4.14 Situation of Hand Picking of Coal by Inhabitants

(4) Changwue gemstone mine (Small-scale mine)

- Deposit type: Pegmatite
- Mining method: Open-pit
- Condition of drainage treatment: There are no discharged water from the mine.
- Condition of ore storage and rock waste dumps: These ore and rock waste are piling on the dumps beside the work area. However, the amount is not of much volume. Target of the mining is mostly quartz and micas.
- Management condition of discharged water and waste dumps: There is no management because the volume does not reach high.

- Others: The planer area reaches approximately 20m^2. Muzimba Gemstone Mining Cooperative Society Ltd. has charged of their equipment for the gems such as polishing machine and so on (Photo 4.17 and 4.18).

Photo 4.15 Digging Site for Gems at Changwue Mine (small-scale)

Photo 4.16 Digging Site for Gems at Changwue Mine (small-scale)

Photo 4.17 Polishing Equipments for Gems at Muzimba Gemstones Cooperative Society

Photo 4.18 Cutting Equipment for Gems at Muzimba Gemstones Cooperative Society

(5) Muzumwanda gemstone mine (Small-scale mine) (Photo 4.19 and 4.20)

- Deposit type: Pegmatite
- Mining method: Open-pit
- Condition of drainage treatment: There are no discharged water from the mine.
- Condition of ore storage and rock waste dumps: These ore and rock waste are piling on the dumps beside the work area. However, it is not much in quantity. Targets of the mining are mostly rose quartz and micas.
- Management condition of discharged water and waste dumps: There is no management because the volume does not reach high.

- Others: Open-pit becomes a pond during rainy season and the water dries up in the dry season. The area of the pond reaches roughly 20m x 20m.
- Measurement of element for the waters: The pH value of the pond water at open-pit shows over 6.65 and there are no values to show high content of some element.

Photo 4.19 Entrance of the Muzumwanda Gem Mine (small-scale)

Photo 4.20 Digging Site of the Muzumwanda Gem Mine (small-scale)

Table 4.4 Result of Simple Analysis by using Pack Test for Water Quality around Object Mines

Sample No	Site Name	Lat. (deg S)	Lon. (deg E)	pH	EC (ms/m)	Temp (deg C)	ME mg/l	Mn mg/l	Cu mg/l	Zn mg/l	Ni mg/l	Cr mg/l	CN- mg/l	F mg/l	Remarks
012201	Mchenga coal mine	10.69907	34.14920	7.76	26.8	27.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	drainage from adit
012202	Mchenga coal mine	10.69907	34.14920	7.62	11.92	27.6	1	<0.5	<0.5	0.4	<0.3	<0.5	<0.02	0	filtered drainage
012203	Mchenga coal mine	10.69773	34.14708	3.01	67.4	26.8	5<	2	<0.5	2<	<0.3	<0.5	<0.02	0.3	drainage from abandoned adit
012204	Mchenga coal mine	10.71425	34.15227	7.41	6.59	25.0	0.1	4	<0.5	0.05	<0.3	<0.5	<0.02	0	stream form water washing plant
012205	Mchenga coal mine	10.71543	34.15425	7.84	49.0	27.6	1	<0.5	<0.5	1	<0.3	<0.5	<0.02	0.2	pond under the water washing plant
012401	Muzumwanda gems mine (small scale)	12.03776	33.65154	6.65	8.89	25.9	0.2	<0.5	<0.5	0.2	<0.3	<0.5	<0.02	0.3	pond in the mine

- pH, EC and Temp were measured by a potable measurement equipment.
- Elements were measured by the Pack Test.

4.3.4 Investigation for Mine Safety

Summaries in the each site are as follows;

(1) Mchenga coal mine

- Mining method: Underground
- Wearing of personal protection equipments: Most miners wear the PPE, however some workers such as drivers of heavy machineries and operators of coal cleaning plants do not wear the PPE.
- Support condition in the underground: Wooden props are basically installed 10m distance in underground (Photo 4.21). Wide space in the underground are allocated pillars wrapped with wood and rock of 0.5m x 0.5m in diameter at 5m distance (Photo 4.21).
- Roof condition in the underground: There are no sheet-piles under the roof (Photo 4.22).
- Open space in the underground: The width of the pit has basically 3.0 m x 2.5m, however the narrow space in the underground is 3m x 2m.
- Rock drill method: Hand drilling by jackhammer.
- Ore conveyer: Belt conveyer from the pit faces the mouth (Photo 4.21). After the transportation, dump tracks are used for transportation from the mouth to the yard.
- Mine ventilation: Ventilators are operated by using generators.
- Others: Clearance between conveyer belt and working pathway are not kept as enough space (Photo 4.21) and the floor is slippery.

Photo 4.21 Condition of Walkway in the Drift of the Mchenga Coal Mine

Photo 4.22 Condition of Roof in the Drift of Mchenga Coal Mine

(2) Kaziwiziwi coal mine

- Mining method: Underground
- Wearing of personal protection equipments: Most miners wear the PPE, however some workers such as drivers of heavy machineries and operators of coal cleaning plants do not wear the PPE.
- Support condition in the underground: Wooden props are basically installed 0.5m distance in the

underground (Photo 4.23). Wide space in the underground are allocated pillars wrapped with block of 0.5m x 0.5m.

- Roof condition in the underground: The condition has basically outcrop, however there are pillars at 0.5m distance and the bedrock has stable condition (Photo 4.24). There are sheet-piles under the roof to prevent rock fall (Photo 4.24).
- Open space in the underground: The width of the pit is basically 3.0 m x 2.5m.
- Rock drill method: Hand drilling by jackhammer is applied.
- Ore conveyer: Man-powered wheelbarrow is used for the ore transportation from the pit face and dump trucks are used for the transportation from the mouth to the yard after the primary crushing.
- Mine ventilation: Natural ventilators by using pipes are used.
- Others: A part of the walkway underground is in slippery condition.

Photo 4.23 Condition of Support in the Drift of Kaziwiziwi Coal Mine

Photo 4.24 Condition of Roof in the Drift of Kaziwiziwi Coal Mine

Photo 4.25 Condition of Support for the Roof in the Drift of Kaziwiziwi Coal Mine

Photo 4.26 Carrying Workers at the Mouth of Drift of Kaziwiziwi Coal Mine

(3) Jalawe coal mine (Small-scale mine)

- Mining method: Underground
- Wearing of personal protection equipments: Most miners wear the PPE, however some workers do not wear the PPE.
- Support condition in the underground: Unknown due to safety reason, however based on their information, there are pillars in the critical places in underground.
- Roof condition in the underground: Outcrop condition.
- Open space in the underground: The width of the pit is approximately 2.0 m x 2.0m.
- Rock drill method: Hand digging by shovel.
- Ore conveyer: Man-powered wheelbarrow is used for ore transportation from the pit face to the coal cleaning site (Photo 4.27 and 4.28).
- Mine ventilation: Nothing.
- Others: The spaces in the underground are very tight. In case if water comes up, pumping by generator is done for drainage.

Photo 4.27 Carrying Workers at the Mouth of Drift in Jalawe Coal Mine (small-scale)

Photo 4.28 Washing and Crushing Place of Kaziwiziwi Coal Mine (small-scale)

(4) Changwue gems mine (Small-scale mine)

- Mining method: Open-pit
- Wearing of personal protection equipments: Nothing.
- Rock drill method: Hand digging by shovel (Photo 4.29 and 4.30).
- Others: Shape of the open-pit shows trench-like, which the depth reaches roughly 15m (Photo 4.29 and 4.30).

Photo 4.29 Digging by Inhabitants
(they do not have PPE.)

Photo 4.30 Condition of Digging Site
(the shape shows trench-like)

(5) Muzumwanda gems mine (Small-scale mine)

- Mining method: Open-pit
- Wearing of personal protection equipments: Nothing (Photo 4.31).
- Rock drill method: Hand digging by shovel.
- Others: Shape of the open-pit shows trench-like, the inside of the pit forms a pond during rainy season (Photo 4.32).

Photo 4.31 Workers From Villages
(they do not have PPE.)

Photo 4.32 Condition of Digging Site
(the shape shows trench-like)

4.4 Zambia

Second investigation in the Zambia was conducted during 28th January to 16th February on 2014.

4.4.1 Schedule

Schedule are shown in Table 4.5.

Table 4.5 Schedule of Second Site Investigation in Zambia (1)

No	Month/ Day	Time	Place	Item of Work	Persons met
1	Jan./28 (Tue)	-	Into Zambia	Traveling	-
2	Jan./29 (Wed)	9:00 - 16:00 -	Lusaka: ZEMA*1 Head Office JICA Office	Meeting for site investigation Explanation of site investigation	Principal Inspector Resident Representative and related staffs
3	Jan./30 (Thu)	7:00 - 14:00 - 15:00 -	To Ndra ZEMA Ndara Office To Kitwe	Traveling Meeting for site investigation Traveling	Senior Inspector
4	Jan./31 (Fri)	8:00 - 9:00 - 10:00 -	Kitwe: Department of Mine Safety Alfred H Knight(analysis laboratory) Kitwe	Meeting for site investigation Meeting for analysis procedure Preparation for site investigation	Senior Inspector Analysis Engineers -
5	Feb./1 (Sat)	8:00 -	Northwest of Kitwe: Mopani Mine / Mufulira, Konkola and Chambishi Mine	Tentative site investigation	-
6	Feb./2 (Sun)		Kitwe:	Preparation of site investigation	-
7	Feb./3 (Mon)	8:00 -	Mopani Mine: around mine are	Sampling of soil and water	-
8	Feb./4 (Tue)	8:00 -	Mopani Mine: around mine area	Meeting with related engineer and sampling of soil and water	Environment engineer of the mine
9	Feb./5 (Wed)	8:00 -	Mopani Mine: around mine area	Sampling of soil and water	Environment engineer of the mine
10	Feb./6 (Thu)	8:00 -	Konkola Mine: around mine area	Meeting with related engineers, visit of mine facilities and sampling of soil and water	Mine Manager and Environment engineer of the mine
11	Feb./7 (Fri)	7:00 -	Konkola Mine: around mine area	Sampling of soil and water	Environment engineers of the mine
12	Feb./8 (Sat)	7:00 -	Mopani Mine: around mine area	Sampling of soil	-
13	Feb./9 (Sun)		Kitwe:	Reporting of inspection	-
14	Feb./10 (Mon)	7:00 -	Konkola Mine: around mine area	Sampling of soil and water	-
15	Feb./11 (Tue)	8:00 - 15:00 -	To Kabwe Kabwe Abandoned Mine: around former mine are	Traveling Meeting with SABLE ZINC and sampling of soil and water	General manager and Environment engineer of SABLE ZINC

*[1] ZEMA: Zambia Environmental Management Agency

Table 4.5 Schedule of Second Site Investigation in Zambia (2)

No	Month/ Day	Time	Place	Item of Work	Persons met
16	Feb./12 (Wed)	8:00 -	Kabwe Abandoned Mine: around former mine are	Sampling of soil and water	Environment engineer of SABLE ZINC
17	Feb./13 (Thu)	8:00 -	Kabwe Abandoned Mine: around former mine are	Sampling of soil and water	Environment engineer of SABLE ZINC
18	Feb./14 (Fri)	8:00 -	To Kitwe Analysis laboratory Department of Mine Safety	Dispatch soil and water Report on the site investigation	Senior Inspectors
19	Feb./15 (Sat)	8:00 -	To Lusaka	Traveling	-
20	Feb./16 (Sun)	-	Lusaka:	Arrangement of information	-
21	Feb./17 (Sun)	9:00 - 14:30 -	Lusaka: ZEMA Head Office JICA Office	Report on the site investigation Report on the site investigation	Senior Inspector Resident Representative and related staffs

*[1] ZEMA: Zambia Environmental Management Agency

4.4.2 Brief Investigation Summary

Site investigations including sampling and analysis of soil, river and discharged water in Zambia was carried out to examine the condition of mine environment in base metal mines which have been concerned about the mine environmental conditions. Tentative meetings with the Department of Mine Safety and Zambia Environment Management Agency were held and selected the investigation sites which are as follows,

1) Mopani copper mine
2) Konkola copper mine
3) Kabwe zinc and lead mine

Location and brief overview of the site investigation are shown in Figure 4.2 and Table 4.6.

During the investigation, the study team joined with inspectors of the Department of Mine Safety, ZEMA and environmental section of the mining company. Objective sites of sampling for soil, river and discharged water consists of tailing dam, waste and slag dump, drainage, spillway, river and ground. Collected soil and water samples obtained from the sites were sent to Alfred H Knight Ltd. for the assay, which is an analytical laboratory in Kitwe. Measurements of pH, EC, water temperature and several metal contents for collected water at onsite were also carried out by study team.

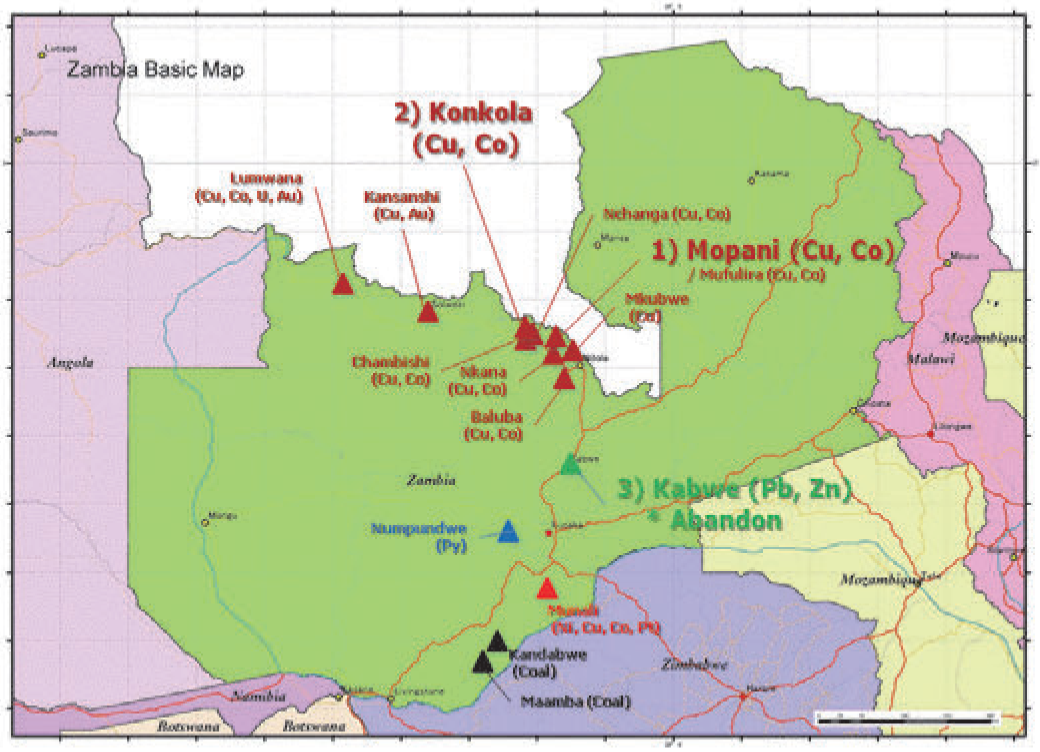


Figure 4.2 Operation Mine and Object Mine for Investigation

Table 4.6 Overview of Investigation Sites

	Site Name	Lat. (deg S)	Lon. (deg E)	Owner	Operation Method*1	Production	Remarks
1)	Mopani Cu-Co Mine	12.54009	28.23334	Glencore International AG (73.1) [Swiss] First Quantum Minerals Ltd (16.9) [Canada] ZCCM (10.0)	UG	1.87Mt/y	Commenced on 2000.
2)	Konkola Cu-Co Mine	8633600 (UTM)	589000 (UTM)	Vedanta Resources plc (79.4)[India] ZCCM (20.6)	UG/OP	n/d	-
3)	Kabwe Abandoned Zn-Pb Mine	14.45170	28.43859	ZCCM (100.0)	UG	-	Closed in early 1990's

*[1] UG: underground, OP: open-pit

4.4.3 Summaries of Investigation for Mine Environment around Mines

Investigations in respect of mine environment and soil and water sampling in mine site and the peripheral area were implemented in the three sites including Mopani copper mine, Konkola copper mine and Kabwe zinc-lead mine. Measurements of pH, EC and water temperature and analyses of several metal contents for collected waters at onsite were also carried out by using Pack Test which is a brief kit for the analysis of elements.

Sampling site were basically included observation stations for water quality monitoring of each mines.

These stations are set in the mouth of spillway from underground, refinery, leaching facility, smelter, tailing dam and so on. Obtaining water wells in the mine area are also included as the sampling sites. Additionally, places of upper stream and downstream of tailing dam and up wind and under the wind of smelter are also included as the sites, the purpose of sampling is to make consideration of influences from the mine.

Summaries of investigation and sampling in each mine are as follows;

(1) Mopani Copper Mine (Photo 4.33, 4.34)

- Mining method: Underground (the depth level reaches approximately -1,400m.)
- Mine facilities: Administration office, shaft, refinery, leaching pond, smelter, slag dump, waste rock dump, tailing dam and so on.
- Condition of drainage treatment: Mine facilities are gathered in one place except tailing dam. These discharge waters relating to the facilities are also gathered in one spillway at the place and the spillway flows in diversion of tailing dam (Photo 4.35). The diversion flows into Mufulira River downstream of the tailing dam. On the other hand, drainage from tailing dam meets with the diversion at west margin of the tailing (Photo 4.36). Both drainages flow directly in the channels through settling pond and dam as a buffer place.
- Condition of slag and waste dump: Main slag dumps are located in two places at south side of smelter (Slag Sump #1) and north side of smelter (Slag Sump #2). Waste rocks are stored in around mine site. Biggest waste dump in the mine locates in the west side of the main facilities of the mine.
- Condition of tailing dam: Current main tailing dam is located in southwest side of the main facilities of the mine. The area of tailing reaches approximately 3km^2 in which tailings from the refinery are deposited. Waste waters including living water from town near the mine also flow in the dam.
- Condition of flue gas from smelter: Flue gas including sulfur dioxide is emitted from funnel of smelter, which the gas flows through the funnel directly except desulfuration filter (Photo 4.37). There is a plan to construct a facility for the desulfuration and the refined sulfuric acid is used for reaching of copper ore and producing the concentrate. However, the plan is still going on so far.
- Management condition of discharged water treatment: Discharged water flows through settling pond and dam into channel and the waters have been managed under the mine. There is a concern of overflow of the discharged waters from the pond and dam during rainy season. However, the critical concerned situation has not happened at the moment. Environment section of the mine has been monitoring water quality relating to meet the standard for industrial discharged water so far, which the elements consist of pH, Cu, Fe, Mn, Co, SO_4 and TDS.
- Other: There is seepage from tailing dam and the drainage water flows directly in the channel (Photo 4.38).

- Simple component measurement of discharged water: Water quality, including several components were measured and analyzed in-situ on the sites (Photo 4.39 and 4.40). Based on the analysis, high Zn values were observed in a part of the sites. The analyzed values are shown in Table 4.7.

Photo 4.33 View of Facilities (shaft and smelter) of Mopani Copper Mine

Photo 4.34 Shaft of Mopani Mine

Photo 4.35 Spillway from Tailing Dam (directly flow in to diversion)

Photo 4.36 Spillway of Tailing Dam (directly flow in to diversion)

Photo 4.37 Flue gas from the Smelter (the flue gas including SO2 is depressing.)

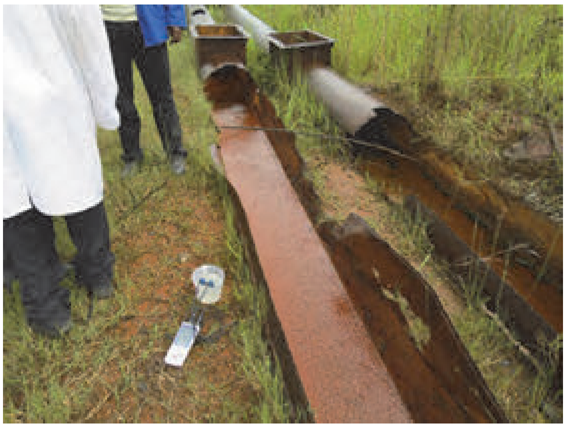


Photo 4.38 Seepage from Tailing Dam (The drainage directly flows into diversion.)

Photo 4.39 Measurement of Water at Monitoring Hole (there are more than ten holes.)

Photo 4.40 Measurement of Water Quality at Slag Dump #2 (pool by rain exist.)

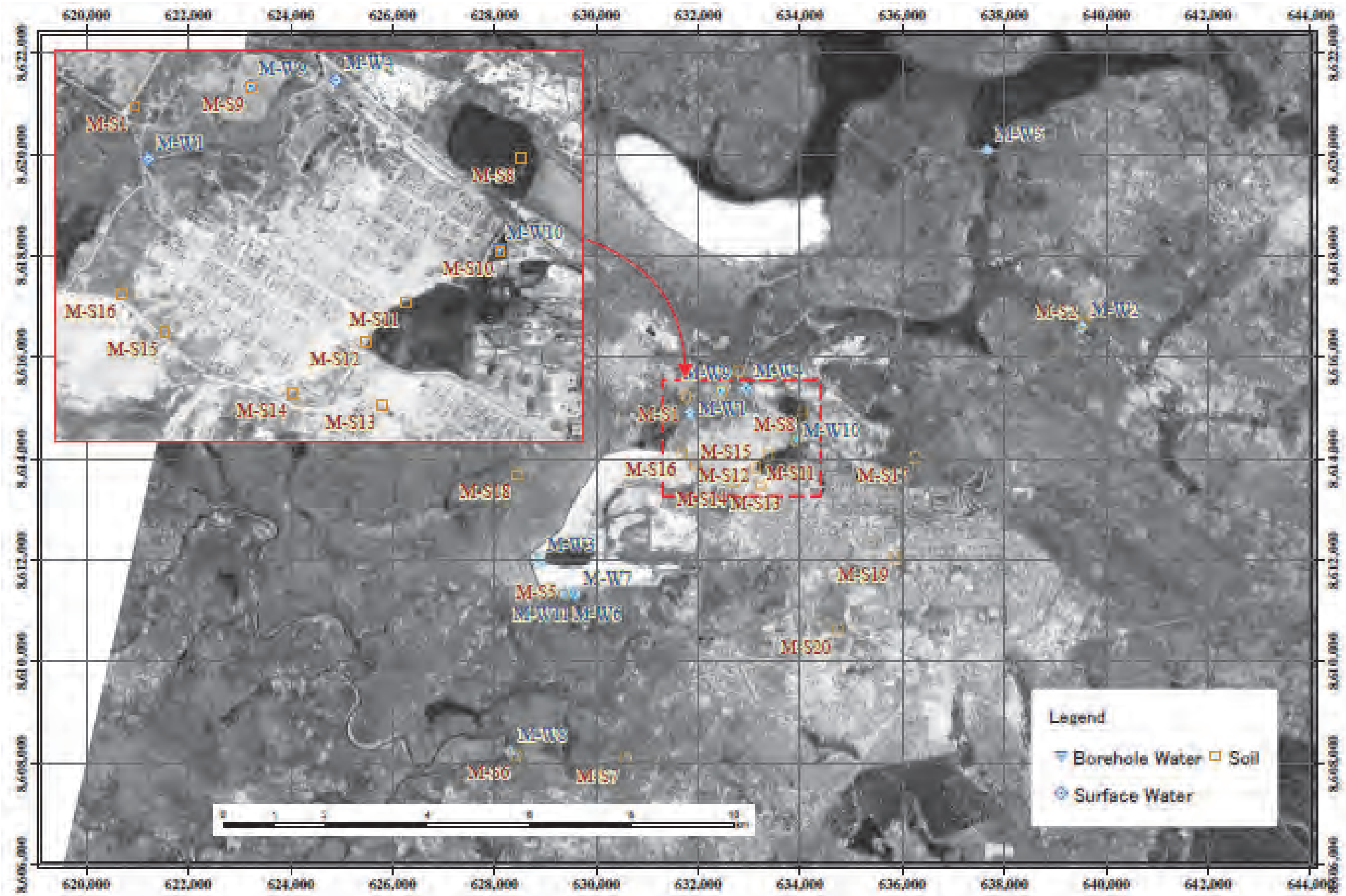


Figure 4.3 Location of Collected Soil and Water Sample at Mopani/Mufulira Mine Site

Table 4.7 Result of Simple Analysis by Using Pack Test for Water Quality around Mopani Mine

Sample No	Site Name	Location (UTM, WGS88)		Physical Features			Result of Pack Test (mg/L)								Remarks
		N-S	E-S	EC*1 (mS/m)	pH	Water Temp (deg C)	Total Cr	Mn	Cu	Zn	Total Metals	Ni	SN*2	F	
M-W1	Mopani	8614906	631837	90	7.72	26.5	<0.5	<0.5	0.5	0.5	0.2	<0.3	non	non	Downstream of drain (Mufulira River)
M-W2	Mopani	8616593	639534	5	6.56	23.8	<0.5	<0.5	<0.5	0.1	0.2	<0.3	non	0.1	Northeast of mine site
M-W3	Mopani	8611975	628858	231	8.15	28.8	<0.5	1.5	<0.5	1.5	3.0	0.3	non	0.8	Final spill way of TD11
M-W4	Mopani	8615377	632942	85	8.46	31.8	<0.5	<0.5	1.5	0.5	0.5	<0.3	non	non	Drainage at #404
M-W5	Mopani	8620054	637671	11	8.15	27.0	<0.5	<0.5	<0.5	0.02	0.2	<0.3	non	non	Water control dam
M-W6	Mopani	8611324	629373	254	6.60	24.1	<0.5	2.0	<0.5	>2	>5	<0.3	non	non	Seepage at TD11
M-W7	Mopani	8611320	629580	113	7.46	25.4	<0.5	<0.5	<0.5	1.0	1.0	<0.3	non	non	Meet point between diversion and past Mufulira River
M-W8	Mopani	8608216	628311	23	7.62	25.3	<0.5	<0.5	0.3	0.4	0.2	<0.3	non	non	Water treatment facility of Kafue River
M-W9	Mopani	8615344	632434	205	8.70	28.1	<0.5	<0.5	<0.5	0.5	0.1	<0.3	non	non	Rock waste dam#17
M-W10	Mopani	8614381	633900	199	6.70	28.7	<0.5	<0.5	<0.5	0.3	0.2	<0.3	non	non	BH15 Groundwater level : -22.60m, Hole depth : 25.0m
M-W11	Mopani	8611311	629493	93	7.77	25.3	<0.5	0.5	<0.5	>2	0.5	<0.3	non	non	BH6 Groundwater level : -2.49m, Hole depth : 18.56m
Ts-M-W1	Mopani	8614673	633993	131.6	7.60	26.0	-	-	-	-	-	-	-	-	Slag dump#2
Ts-M-W2	Mopani	8613685	628443	-	5.68	22.8	-	-	-	-	-	-	-	-	Normal soil

*1 Electric Conductivity mS/m= 10 x (μS/cm)
General features of EC in Japan: Rain water 5 - 30, Environmental surface water 20 - 60, Affected water : >100, Abnormal water >1000 μS/cm.

*2 SN: Cyanide

(2) Konkola Copper Mine (Photo 4.41 and 4.42)

- Mining method: Underground (the depth level reaches approximately -1,400m.)
- Mine facilities: Administration office, shaft, crushing plant, refinery plant, waste dump, tailing dam and so on.
- Condition of drainage treatment: Mine facilities are gathered in one place except tailing dam. These discharge waters relating to the facilities are also gathered in spillways at the place (Photo 4.43) and the spillways flow in tributaries of the Kafue River. These tributaries joins in mainstream of the Kafue River, located approximately 4km downstream. Tailings from the refinery plant are discharged through slurry pipe line in the tailing dam of the north side of the mine site (Photo 4.44).
- Condition of waste dump: Main waste rock dump is located in the west side of facilities. The present amount of the waste is few.
- Condition of tailing dam: Tailing dam located in north of the main facilities of mine. The area of tailing dam corresponds to confluent of three rivers. The dam has an area of 5km x 3km. These rivers are used for domestic and industrial water supply (Photo 4.45).
- Management condition of discharged water: Discharged waters flows through settling pond and dam into channel and the waters have been managed under the mine. There is a concern of overflow of the discharged waters from the pond and dam during rainy season as well as the Mopani mine. However, the critical concerned situation has not happened at the moment. Environment section of the mine has been monitoring water quality relating to meet the standard for industrial discharged water so far, which the elements consist of pH, temperature, BOD and Cu.
- Other: There is seepage from tailing dam and the drainage water flows directly in the channel. Water from a monitoring well near the tailing dam is used for domestic use for the residents (Photo 4.46).
- Simple component measurement of discharged water: Water quality, including several components were measured and analyzed in-situ at spillways and rivers in the mine area (Photo 4.47 and 4.48). Relatively high-acidic water samples and high zinc samples are observed in a part of the sites. The analyzed values are shown in Table 4.8.

Photo 4.41 Shaft of Konkola Mine (right side is used for carrying crude ore from under ground)

Photo 4.42 View of the Facilities (conveyor, mill and concentrator) in Konkola Mine

Photo 4.43 Drainage from Mine Facilities and Underground (the discharged water flows in Kafue River)

Photo 4.44 Discharge to Tailing Dam (tailings are conveyed by slurry pipe from the concentrator)

Photo 4.45 Water Pumping at Tailing Dam (the water used for industrial and domestic water near the tailing)

Photo 4.46 Hand Pumping by Inhabitants at Water Quality Monitoring Hole (the water has characteristic of acidic)

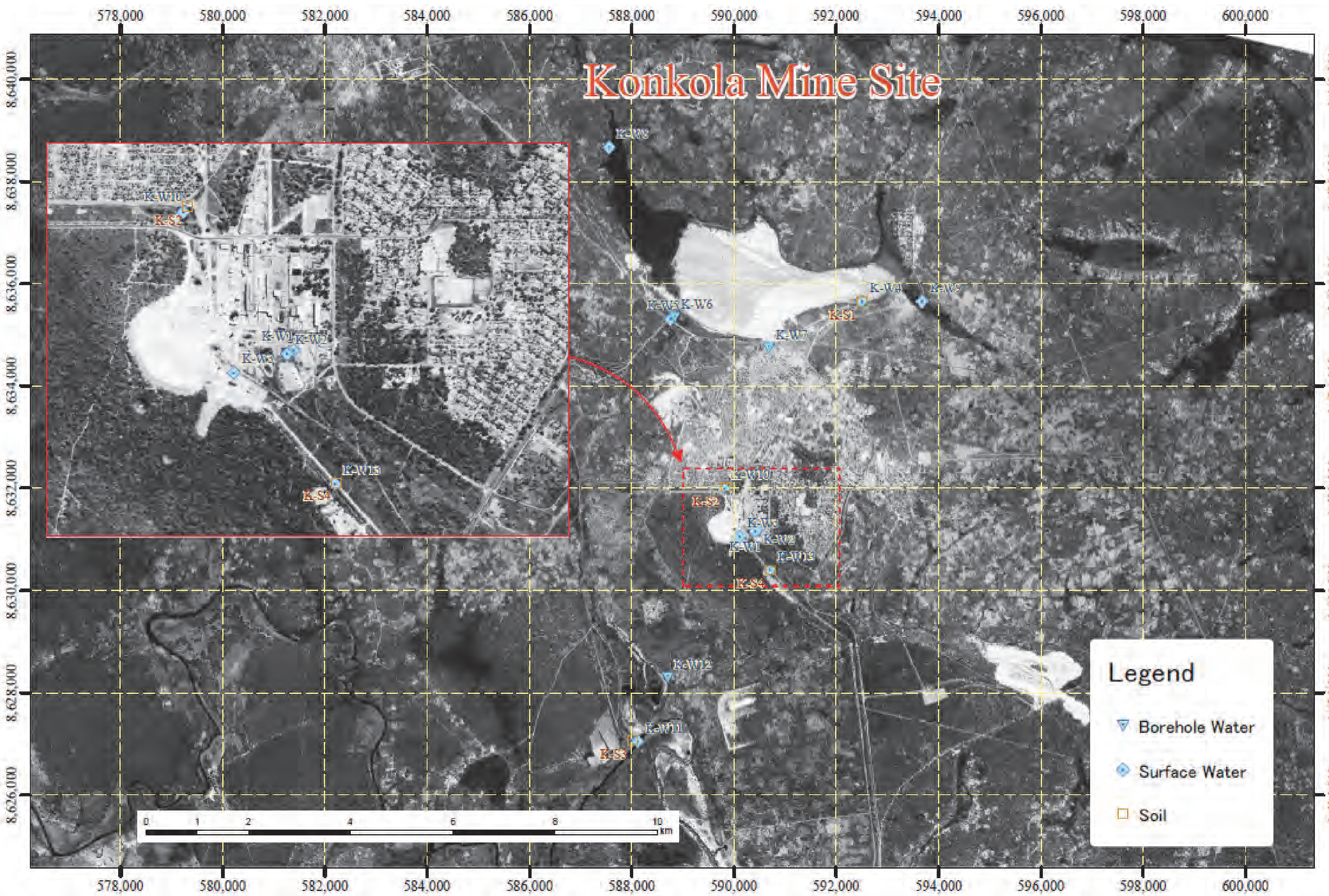


Figure 4.4 Location of Collected Soil and Water Sample at Konkola Mine Site

Table 4.8 Result of Simple Analysis by Using Pack Test for Water Quality around Konkola Mine

Sample No	Site Name	Location (UTM, WGS88)		Physical Features			Result of Pack Test (mg/L)								Remarks
		N-S	E-S	EC*1 (mS/m)	pH	Water Temp (deg C)	Total Cr	Mn	Cu	Zn	Total Metals	Ni	SN*2	F	
K-W1	Konkola	8631175	590450	46	8.49	27.7	<0.5	<0.5	0.5	0.5	0.4	<0.3	non	0.4	Drainage water from concentrator
K-W2	Konkola	8631155	590411	48	8.15	28.6	<0.5	<0.5	<0.5	1.0	0.5	<0.3	non	non	Mine water of UG
K-W3	Konkola	8631039	590097	48	8.06	27.8	<0.5	<0.5	0.5	0.5	0.5	<0.3	non	non	Drainage from underground (main)
K-W4	Konkola	8635650	592495	49	8.53	29.4	<0.5	<0.5	0.5	0.2	0.5	<0.3	non	0.4	Drainage from concentrator
K-W5	Konkola	8635308	588749	30	8.58	25.2	<0.5	<0.5	<0.5	0.1	0.1	<0.3	non	non	Spillway of tailing dam
K-W6	Konkola	8635345	588825	2	5.32	24.3	<0.5	<0.5	<0.5	0.2	0.1	<0.3	non	non	Groundwater level : -1.68m
K-W7	Konkola	8634723	590678	34	6.13	23.2	<0.5	<0.5	<0.5	0.1	0.2	<0.3	non	non	Groundwater level : -1.00m
K-W8	Konkola	8638662	587550	31	7.94	24.1	<0.5	<0.5	<0.5	0.05	0.2	<0.3	non	non	Upper stream of mine
K-W9	Konkola	8635645	593668	22	6.19	22.7	<0.5	<0.5	<0.5	>2	0.2	<0.3	non	non	River at southeast of tailing dam
K-W10	Konkola	8631988	589802	52	8.39	24.9	<0.5	<0.5	0.5	0.5	0.5	<0.3	non	non	Drainage from mine facilities
K-W11	Konkola	8627037	588111	13	7.30	25.4	<0.5	<0.5	<0.5	0.05	0.1	<0.3	non	non	Lower stream of mine site
K-W12	Konkola	8628293	588696	11	5.41	22.5	<0.5	<0.5	0.5	0.05	0.2	<0.3	non	non	Groundwater level : -4.13m

*1 Electric Conductivity mS/m= 10 x (µS/cm)
General features of EC in Japan: Rain water 5 - 30, Environmental surface water 20 - 60, Affected water : >100, Abnormal water >1000 µS/cm.
*2 SN: Cyanide

Photo 4.47 Water Quality Analysis by Pack Test (analysis were conducted with mine's engineers.)

Photo 4.48 Water Quality Analysis at Peripheral Streams of Mine Site

(3) Kabwe Abandon Zinc-Lead Mine

- Mining method at the time of operation: Underground
- Current situation (General): Kabwe Mine operated during 1905-1995, and was closed by ZCCM (Zambia Consolidated Copper Limited). Most remaining facilities such as crude ore and refinery plants were took over by Sable Zinc Ltd (Photo 4.49 and 4.50). The Sable Zinc has been producing copper cathodes by SX-EW to reuse the facilities. Crude ore for the processing consists of oxidized ore and the Sable Zinc purchase the ore from DR Congo. There are vacant lots such shaft, tailing dam, slag and waste dump around the processing facilities. These lots are mostly owned by the Environment Processing Ltd and the Sable Zinc owns parts of the lots. In these properties, the Environment Processing are constructing processing plants for Zinc in a part of the area. The Sable Zinc are reusing former tailing dam as a circulating pond for leaching waste fluid from copper smelting.
- Current situation (Mine environment): Concerns of mine environment at the moment are diffusion of sulfide and related components through soil and groundwater from tailing dam, slag and waste dump which were used for former mine facilities. Media has reported that related elements are concentrated in the peripheral area of the mine and the there are some kind of influences to residents living in the vicinity of the area.

  ZCCM was made reports for the rehabilitation and closure step of the mine on 1995 when mine was closed. After the reporting, ZCCM-IH plc., also made reports in respect of the site rehabilitation and environment management plan on 2006. As it stands at the moment, the ZCCM-IH plc is supposed to implement the plan and commence the site operation.

  Also, the Stable Zinc are reusing former facilities and processing SX-EW refining for copper. However, the industrial waste water has not been discharged outside and the waste water is circulating in the facilities.
- Current situation (Former tailing dam, slag and waste dump): Discharged water is not drained from

remaining pond into the periphery of the mine during the operation of the Sable Zinc. The former tailing dam was basically backfilled by slag and waste of previous mine (Photo 4.51 and 4.52).

- Current situation (Monitoring for groundwater): Sable Zinc Ltd. has been monitoring quality of groundwater in 4 sites at water wells, 2 sites at former shafts and 3 sites at stream around mine, which the components of the monitoring are pH, Pb, Zn, Cu and Co.
- Simple component measurement of discharged water at the monitoring sites: Water quality including several components were measured and analyzed in-situ at the monitoring sites by Sable Zinc, located in water wells and streams around the mine (Photo 4.53 and 4.54). Most sites have high zinc and metal contents. The analyzed values are shown in Table 4.9.

Photo 4.49 Entrance of Former Mine Facilities (Sable Zinc Ltd has bee using the facilities.)

Photo 4.50 SX-EW Plant in the Lot (Sable Zinc were reconstructed for the refinery.)

Photo 4.51 Former Tailing Dam (slag and waster were refilled at the time of closure.)

Photo 4.52 Former Tailing Dam and Slag Dump (these are remaining so far.)

Photo 4.53 Water Collecting at Water Monitoring Sampling at Well of BW-3 near Former Tailing Dam

Photo 4.54 Underground Water Davis Shaft in Former Mine Facilites

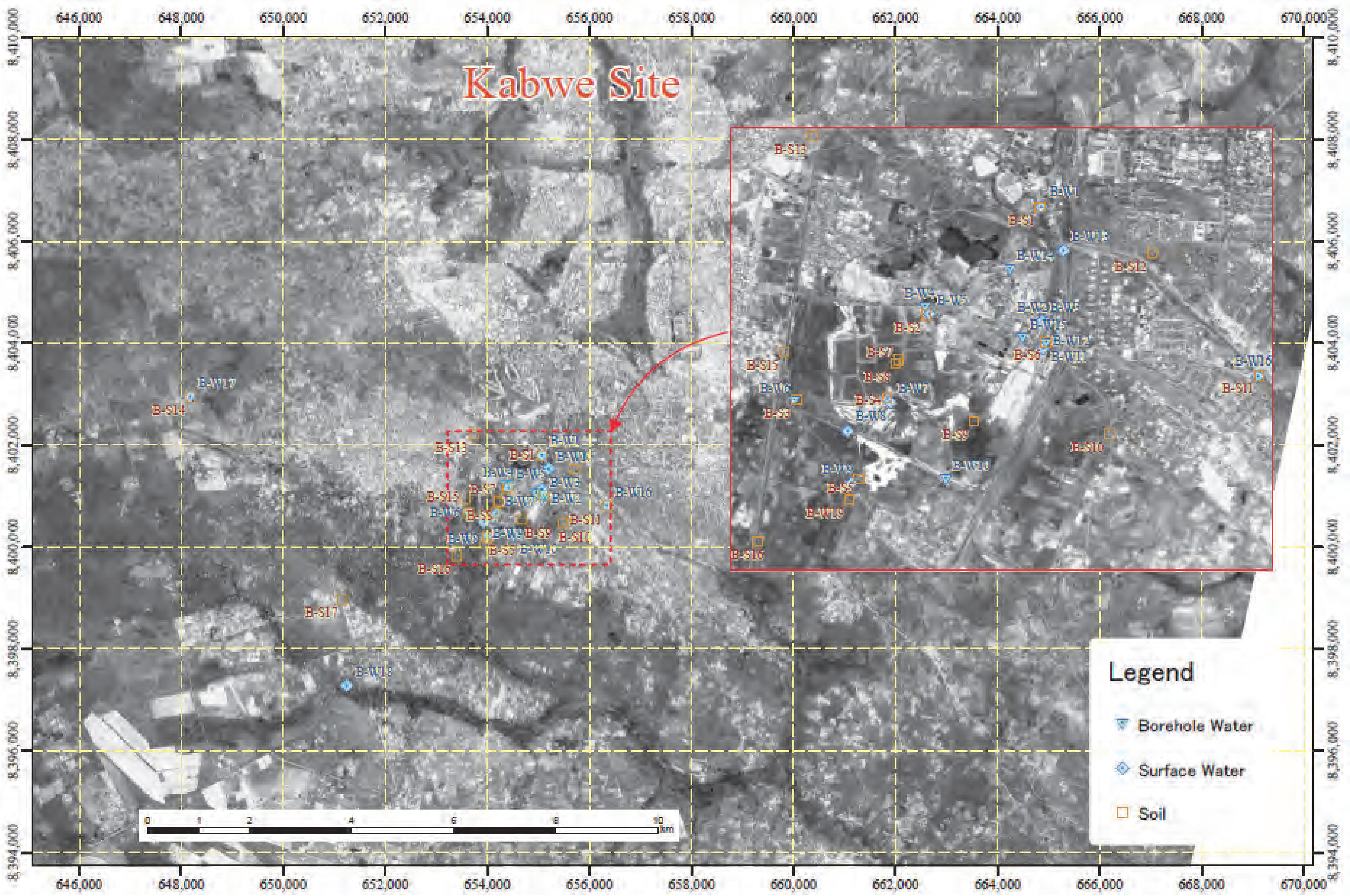


Figure 4.5 Location of Collected Soil and Water Sample at Kabwe Abandoned Mine Site

Table 4.9 Result of Simple Analysis by Using Pack Test for Water Quality around Kabwe Mine (1)

Sample No	Site Name	Location (UTM, WGS88)		Physical Features			Result of Pack Test (mg/L)								Remarks
		N-S	E-S	EC*1 (mS/m)	pH	Water Temp (deg C)	Total Cr	Mn	Cu	Zn	Total Metals	Ni	SN*2	F	
B-W1	Kabwe (Drainage)	8401801	655059	35	9.08	27.6	<0.5	<0.5	<0.5	0.5	0.5	<0.3	non	non	Drainage from Plant site of Kabwe Mine
B-W2	Kabwe (Drainage)	8401115	655091	24	8.02	25.9	<0.5	<0.5	<0.5	0.35	0.5	<0.3	non	non	Drainage from Plant site of Kabwe Mine
B-W3	Kabwe (Drainage)	8401123	655062	30	8.41	29.5	<0.5	0.75	0.5	1.5	1.5	<0.3	non	0.4	Drainage from Plant site of Kabwe Mine
B-W4	Kabwe (GW-4)	8401205	654373	52	7.00	24.5	<0.5	<0.5	<0.5	>2	1.5	<0.3	non	0.4	Groundwater level : -several m
B-W5	Kabwe (Tailing dam)	8401163	654398	53	6.62	21.4	<0.5	2.0	1.5	>2	>5	<0.3	non	0.8	Small pond in mixture of tailing and slag
B-W6	Kabwe (GW-3)	8400649	653601	31	7.61	24.8	<0.5	2.5	<0.5	>2	3.5	<0.3	non	non	Groundwater level : -several m
B-W7	Kabwe (Settlement pond)	8400645	654170	904	3.25	23.1	<0.5	unknown	1.5	>2	>5	<0.3	unknown	0.4	Pond for reutilization of Cu leaching
B-W8	Kabwe (Seepage from pond)	8400480	653919	477	6.35	25.2	<0.5	unknown	>10	>2	>5	<0.3	non	non	Cu-oxides are generated in the drainage
B-W9	Kabwe (Wetland)	8400168	653942	378	6.39	23.4	<0.5	8.0	>10	>2	>5	<0.3	non	0.4	Combined wetland of seepage and natural water
B-W10	Kabwe (GW-2)	8400191	654496	260	7.18	24.7	<0.5	8.0	0.8	>2	>5	<0.3	non	0.4	Assembled Cu seeped water

*1 Electric Conductivity mS/m= 10 x (µS/cm)
General features of EC in Japan: Rain water 5 - 30, Environmental surface water 20 - 60, Affected water : >100, Abnormal water >1000 µS/cm.
*2 SN: Cyanide

Table 4.9 Result of Simple Analysis by Using Pack Test for Water Quality around Kabwe Mine (2)

Sample No	Site Name	Location (UTM, WGS88)		Physical Features			Result of Pack Test (mg/L)								Remarks
		N-S	E-S	EC*1 (mS/m)	pH	Water Temp (deg C)	Total Cr	Mn	Cu	Zn	Total Metals	Ni	SN*2	F	
B-W11	Kabwe (Intake)	8400965	655066	191	6.41	25.1	<0.5	15.0	>10	>2	>5	<0.3	non	0.2	Recirculated leached water intake at plant site
B-W12	Kabwe (GW-1)	8400989	655083	215	6.51	25.5	<0.5	2.0	0.5	>2	>5	<0.3	non	0.2	Groundwater level : -several m
B-W13	Kabwe (Lower stream)	8401540	655190	112	7.90	25.6	<0.5	2.0	1.0	>2	>5	<0.3	non	0.4	Stream from east of mine site
B-W14	Kabwe (Shaft water)	8401426	654873	62	8.35	24.4	<0.5	<0.5	<0.5	0.5	0.5	<0.3	non	non	Shallow groundwater at shaft
B-W15	Kabwe (Shaft water)	8401025	654948	85	7.76	24.9	<0.5	<0.5	<0.5	2.0	1.5	<0.3	non	non	Relatively deeper groundwater at shaft
B-W16	Kabwe (Lower stream)	8400805	656332	90	7.16	22.9	unknown	unknown	unknown	>2	>5	unknown	unknown	non	Terbidity (and SS) is very high and water colour is light brown.
B-W17	Kabwe (Upper stream)	8402945	648175	5	7.15	25.5	<0.5	1.0	0.3	0.20	0.5	<0.3	non	0.4	Uppermost location in the site
B-W18	Kabwe (Upper stream)	8397271	651258	26	6.97	23.5	<0.5	1.0	0.5	>2	3.5	<0.3	non	non	At culvert bridge along the main road
B-W19	Kabwe (SW4)	8400073	653928	198	6.83	26.0	<0.5	2.0	1.5	>2	>5	<0.3	non	0.4	Water is likely same as B-W8 (?).
TS-B-W 1	Kabwe (Pond)	8400683	655338												Past open-pit at east of mine site

*1 Electric Conductivity mS/m= 10 x (µS/cm)
General features of EC in Japan: Rain water 5 - 30, Environmental surface water 20 - 60, Affected water : >100, Abnormal water >1000 µS/cm.
*2 SN: Cyanide

4.4.4 Water Environment around the Mine Sites

Water environment around the Mopani Mine, Konkola Mine and Kabwe Mine sites are described as below.

(1) Classification of Water

The water around the mine site is classified into five groups, including 1) drainage water, 2) seeped water, 3) mine water, 4) groundwater and 4) surface water.

- Drainage water consists of discharge water from the mine facilities, including concentrator, tailings dam, smelter, etc.
- Seeped water consists of seeped water from the mine facilities, including waste dump area, tailings dam, etc.
- Mine water is discharge water from underground and open pit mine sites.
- Groundwater is pumped up water from monitoring wells, vertical shafts and water wells.
- Surface water is mainly river water, and river water at upper and down streams of the river is generally taken and analyzed.

The results of water classification and simple method analysis (called as Pack Test) are shown in Table 4.7, 4.8 and 4.9.

(2) Flow of Water

Flow of water in the each mine site is shown in Figure 4.6 (1), (2) and (3), respectively. Coloring of the flow is same as that of Table 4.10.

a. Mopani Mine

River water in the upper stream was taken at the sampling points of M-W2 and M-W5 in the Mopani mine site, and the river water in the downstream is M-W8. Vast volume of drainage water from the mine facilities, including Cu Concentrator, underground mine water, etc. was gathered into settlement pond, taken as M-W1. Mine water was taken and analyzed as M-W4. Seeped water was taken and analyzed from two points of the waste dump area and tailings dam. Groundwater at the two points of M-W9 and M-W6 as monitoring wells was taken and analyzed.

b. Konkola Mine

River water in the upper stream was taken at K-W9 in the Konkola mine site, and the river water in the downstream was taken at four points of K-W4, K-W11, K-W15 and K-W16. Drainage water from Cu Concentrator is K-W1, K-W3 and K-W13. The volume of drainage water from the tailings dam is a little, only overflow water during rainy season. Vast volume of underground mine water was taken as K-W2 in settlement pond of which the mine water is used as public water supply. Seeped water from the tailings dam was taken as K-W5, and gathered water including seeped water from the tailings dam was taken as K-W14. Groundwater at the two points of K-W6 and K-W7 as monitoring wells was taken and analyzed.

c. Kabwe Mine

River water in the upper stream was taken at B-W17 in the Kabwe mine site, and the river water in the downstream was taken at three points of B-W18, B-W13, and B-W16. Although all of the drainage water from Cu Smelter is recycled, the water in various process in the site as B-W3 to B-W15 (13 points) was taken and analyzed. However, domestic water, rain water, etc. as B-W1 and B-W2 are discharged to the outside of the mine site. Surface water of B-W19 is possibility to be included drainage water from the mine site. No seeped water from old tailings dam is occurred. Groundwater at the four points of B-W12, B-W4, B-W6 and B-W10 as monitoring wells was taken and analyzed.

4.4.5 Results of Simple Analysis of Water by Pack Test

Contamination conditions evaluated by the simple analytical results by Pack Test in each mine site are shown in Figures 4.7 (1), (2) and (3).

(1) Mopani Mine Site

Mopani mine site area shows to be relatively high concentration of Zn, Cu and Mn.

Seeped water from the tailings dam and waste dump area shows to be relatively high concentration of Zn (more than 2 mg/L). And the area showing relatively high concentration of Zn is same as the area of mine facilities.
The concentration of Cu is less than 0.5 mg/L, but mine water shows 1.5 mg/L Cu. The concentration of Mn of spill water from the tailings dam is relatively high.

(2) Konkola Mine Site

The metal concentration in the Konkola mine site is relatively lower than that of the Mopani mine site. However, the Zn concentration is higher than in the mine site.

Groundwater in the tailings dam (K-W6) and its downstream (K-W15) is acidic of pH 5.

(3) Kabwe Mine Site

Kabwe mine site area shows to be relatively high concentration of Zn, Cu and Mn. Relatively high concentration of Zn (> 2 mg/L) is found in whole area of mine site and downstream, thus Zn is likely to be diffused widely around the mine site. As high concentration of Cu (more than 10 mg/L) is found only around the present Cu Smelter, source of Cu is thought to be derived from preset Cu Smelter, however it is limited in the old mine site.

Relatively high concentration of Mn (more than 2 mg/L) is found around the mine site, almost same area of Cu. Source of Mn is also thought to be derived from preset Cu Smelter.

Table 4.10 Result of Simple Analysis by using Pack Test for Water Quality

(1) Mopani Mine Site

Sample No.	Loction	Name of River /Bore Hole /Water Well	Physical Features			Result of Pac Test (mg/L)								Remarks
			Electric Conductivity (mS/m) *1	pH	Water Temperature (degree C.)	Total -Cr	Mn	Cu	Zn	Total - Metals	Ni	SN *2	F	
M-W1	Mopani	Mufulira R.	90	7.72	26.5	<0.5	<0.5	0.5	0.5	0.2	<0.3	non	non	Containing drainage water from plantsite of MCM
M-W2	Mopani	Chibwe R.	5	6.56	23.8	<0.5	<0.5	<0.5	0.1	0.2	<0.3	non	0.1	Northeast of mine site
M-W3	Mopani	Spillway of TD11	231	8.15	28.8	<0.5	1.5	<0.5	1.5	3.0	<0.3	non	0.8	Final spillway of TD11
M-W4	Mopani	Spillway at #404	85	8.46	31.8	<0.5	<0.5	1.5	0.5	0.5	<0.3	non	non	Mine water of underground
M-W5	Mopani	Mufulira R. (natural)	11	8.15	27.0	<0.5	<0.5	<0.5	0.02	0.2	<0.3	non	non	Upper stream of mine site of MCM
M-W6	Mopani	Seepage from TD11	254	6.60	24.1	<0.5	2.0	<0.5	>2	>5	<0.3	non	non	Seepage at TD11
M-W7	Mopani	Mufulira R.	113	7.46	25.4	<0.5	<0.5	<0.5	1.0	1.0	<0.3	non	non	Meet point between diversion and past Mufulira River
M-W8	Mopani	Kafue R.	23	7.62	25.3	<0.5	<0.5	0.3	0.4	0.2	<0.3	non	non	Water intake facility of Kafue River
M-W9	Mopani	Waste rock dump	205	8.70	28.1	<0.5	<0.5	<0.5	0.5	0.1	<0.3	non	non	Small pond in Waste rock dump #17
M-W10	Mopani	BH (MUF)-15	199	6.70	28.7	<0.5	<0.5	<0.5	0.3	0.2	<0.3	non	non	Groundwater level : -22.60m, Hole depth : 25.0m
M-W11	Mopani	BH-6	93	7.77	25.3	<0.5	0.5	<0.5	>2	0.5	<0.3	non	non	Groundwater level : -2.49m, Hole depth : 18.56m

*1 mS/m = 10 x (μS/cm)

* unknown: Concentrate value could not be detected due to abnormal reaction colour.

Drainage
Seepage water
Mine water from underground / open pit
Surface (stream) water
Groundwater

Table 4.10 Result of Simple Analysis by using Pack Test for Water Quality

(2) Konkola Mine Site

Sample No.	Loction	Name of River /Bore Hole /Water Well	Physical Features			Result of Pac Test (mg/L)								Remarks
			Electric Conductivity (mS/m) *1	pH	Water Temperature (degree C.)	Total -Cr	Mn	Cu	Zn	Total - Metals	Ni	SN *2	F	
K-W1	Konkola	Drainage	46	8.49	27.7	<0.5	<0.5	0.5	0.5	0.4	<0.3	non	0.4	Drainage water from Concentrator of KCM
K-W2	Konkola	Mine water	48	8.15	28.6	<0.5	<0.5	<0.5	1.0	0.5	<0.3	non	non	Mine water of underground of KCM
K-W3	Konkola	Drainage	48	8.06	27.8	<0.5	<0.5	0.5	0.5	0.5	<0.3	non	non	Drainage from underground (main)
K-W4	Konkola	Drainage	49	8.53	29.4	<0.5	<0.5	0.5	0.2	0.5	<0.3	non	0.4	Drainage from concentrator
K-W5	Konkola	Spillway of tailings	30	8.58	25.2	<0.5	<0.5	<0.5	0.1	0.1	<0.3	non	non	Spillway of tailings dam
K-W6	Konkola	SDH-17	2	5.32	24.3	<0.5	<0.5	<0.5	0.2	0.1	<0.3	non	non	Groundwater level : -1.68m
K-W7	Konkola	SDH-19	34	6.13	23.2	<0.5	<0.5	<0.5	0.1	0.2	<0.3	non	non	Groundwater level : -1.00m
K-W8	Konkola	tailings dam	31	7.94	24.1	<0.5	<0.5	<0.5	0.05	0.2	<0.3	non	non	Water intake in tailings dam
K-W9	Konkola	Natural stream	22	6.19	22.7	<0.5	<0.5	<0.5	0.2	0.2	<0.3	non	non	River at southeast of tailings dam
K-W10	Konkola	Drainage	52	8.39	24.9	<0.5	<0.5	0.5	0.5	0.5	<0.3	non	non	Drainage from mine facilities
K-W11	Konkola	Kafue R.	13	7.30	25.4	<0.5	<0.5	<0.5	0.05	0.1	<0.3	non	non	Kafue Raw Water Intake
K-W12	Konkola	KO4	11	5.41	22.5	<0.5	<0.5	0.5	0.05	0.2	<0.3	non	non	Groundwater level : -4.13m
K-W13	Konkola	Drainage	49	8.11	27.2	<0.5	<0.5	0.5	0.5	0.5	<0.3	non	non	Combined drainage of concentrator and underground
K-W14	Konkola	Drainage	30	8.04	24.6	<0.5	<0.5	<0.5	0.1	0.1	<0.3	non	non	Combined drainage of spill and seepage at tailings dam
K-W15	Konkola	Natural stream	6	7.18	22.2	<0.5	<0.5	<0.5	0.2	0.2	<0.3	non	non	South of mine site
K-W16	Konkola	Kafue R.	15	7.30	25.4	<0.5	<0.5	<0.5	0.1	0.2	<0.3	non	non	Main stream of Kafue River

*1 mS/m = 10 x (μS/cm)

* unknown: Concentrate value could not be detected due to abnormal reaction colour.

- Drainage
- Seepage water
- Mine water from underground / open pit
- Surface (stream) water
- Groundwater

Table 4.10 Result of Simple Analysis by using Pack Test for Water Quality

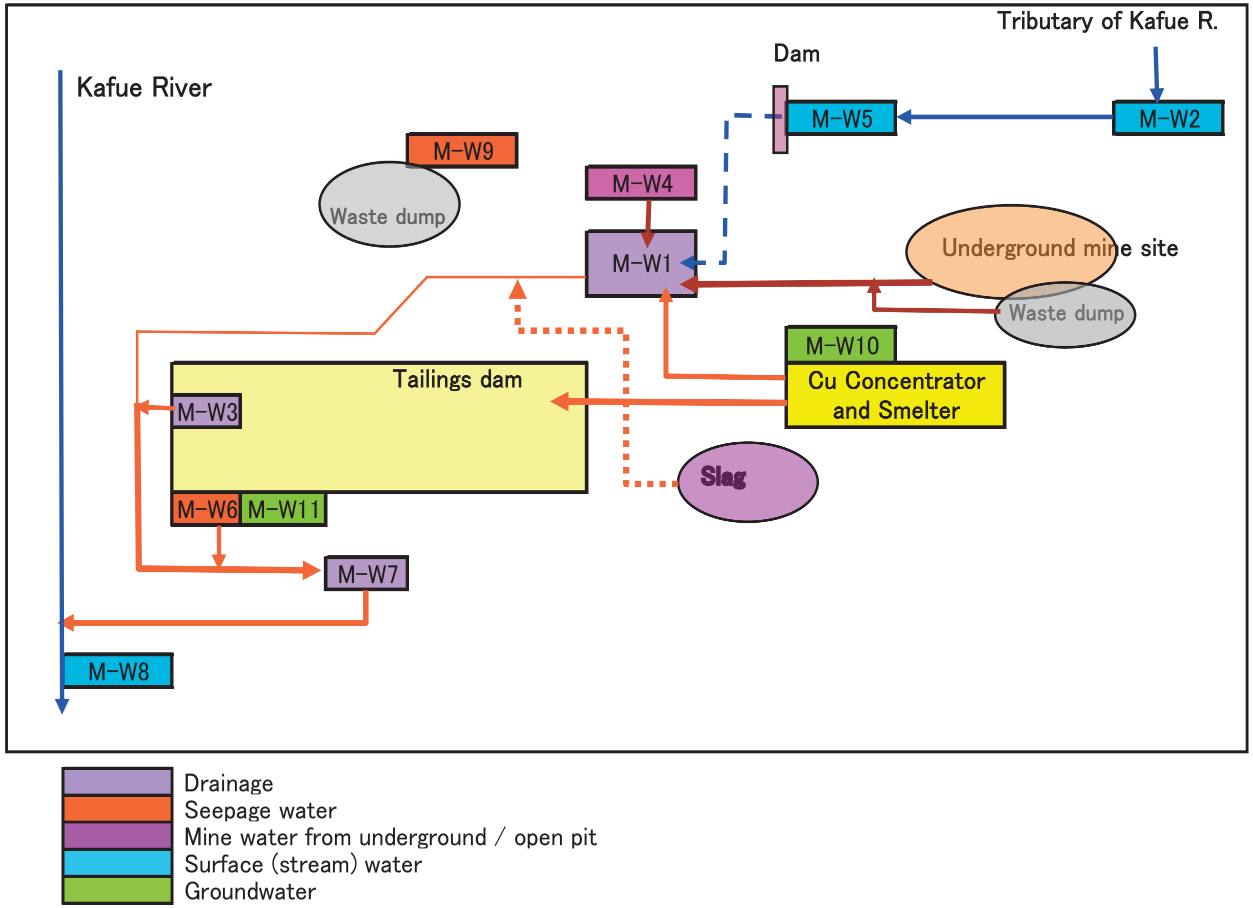
(3) Kabwe Mine Site

Sample No.	Loction	Name of River /Bore Hole /Water Well	Physical Features			Result of Pac Test (mg/L)								Remarks
			Electric Conductivity (mS/m) *1	pH	Water Temperature (degree C.)	Total -Cr	Mn	Cu	Zn	Total - Metals	Ni	SN *2	F	
B-W1	Kabwe	Drainage	35	9.08	27.6	<0.5	<0.5	<0.5	0.5	0.5	<0.3	non	non	Drainage from Plant site of Kabwe Mine
B-W2	Kabwe	Drainage	24	8.02	25.9	<0.5	<0.5	<0.5	0.35	0.5	<0.3	non	non	Drainage from Plant site of Kabwe Mine
B-W3	Kabwe	Drainage	30	8.41	29.5	<0.5	0.75	0.5	1.5	1.5	<0.3	non	0.4	Drainage from Plant site of Kabwe Mine
B-W4	Kabwe	GW-4	52	7.00	24.5	<0.5	<0.5	<0.5	>2	1.5	<0.3	non	0.4	Groundwater level : -several m
B-W5	Kabwe	tailingss dam	53	6.62	21.4	<0.5	2.0	1.5	>2	>5	<0.3	non	0.8	Small pond in mixture of tailings and slag
B-W6	Kabwe	GW-3	31	7.61	24.8	<0.5	2.5	<0.5	>2	3.5	<0.3	non	non	Groundwater level : -several m
B-W7	Kabwe	Settlement Pond	904	3.25	23.1	<0.5	unknow	1.5	>2	>5	<0.3	unknow	0.4	Pond for reutilization of Cu leaching
B-W8	Kabwe	Seepage from pond	477	6.35	25.2	<0.5	unknow	>10	>2	>5	<0.3	non	non	Cu-oxides are generated in the drainage
B-W9	Kabwe	Wetland	378	6.39	23.4	<0.5	8.0	>10	>2	>5	<0.3	non	0.4	Combined wetland of seepage and natural water
B-W10	Kabwe	GW-2	260	7.18	24.7	<0.5	8.0	0.8	>2	>5	<0.3	non	0.4	Assembled Cu seeped water
B-W11	Kabwe	Intake	191	6.41	25.1	<0.5	15	>10	>2	>5	<0.3	non	0.2	Recirculated leached water intake at plant site
B-W12	Kabwe	GW-1	215	6.51	25.5	<0.5	2.0	0.5	>2	>5	<0.3	non	0.2	Groundwater level : -several m
B-W13	Kabwe	Lower stream	112	7.90	25.6	<0.5	2.0	1.0	>2	>5	<0.3	non	0.4	Stream from east of mine site
B-W14	Kabwe	Shaft water	62	8.35	24.4	<0.5	<0.5	<0.5	0.5	0.5	<0.3	non	non	Shallow groundwater at shaft
B-W15	Kabwe	Shaft water	85	7.76	24.9	<0.5	<0.5	<0.5	2.0	1.5	<0.3	non	non	Relatively deeper groundwater at shaft
B-W16	Kabwe	Lower stream	90	7.16	22.9	unknow	unknow	unknow	>2	>5	unknow	unknow	non	At bridge, terbidity (and SS) is very high and water colour is light brown.
B-W17	Kabwe	Upper stream	5	7.15	25.5	<0.5	1.0	0.3	0.2	0.5	<0.3	non	0.4	Uppermost location in the site
B-W18	Kabwe	Upper stream	26	6.97	23.5	<0.5	1.0	0.5	>2	3.5	<0.3	non	non	At culvert bridge along the main road
B-W19	Kabwe	SW4	198	6.83	26.0	<0.5	2.0	1.5	>2	>5	<0.3	non	0.4	Water is likely same as B-W8 (?).

*1 mS/m = 10 x (μS/cm)

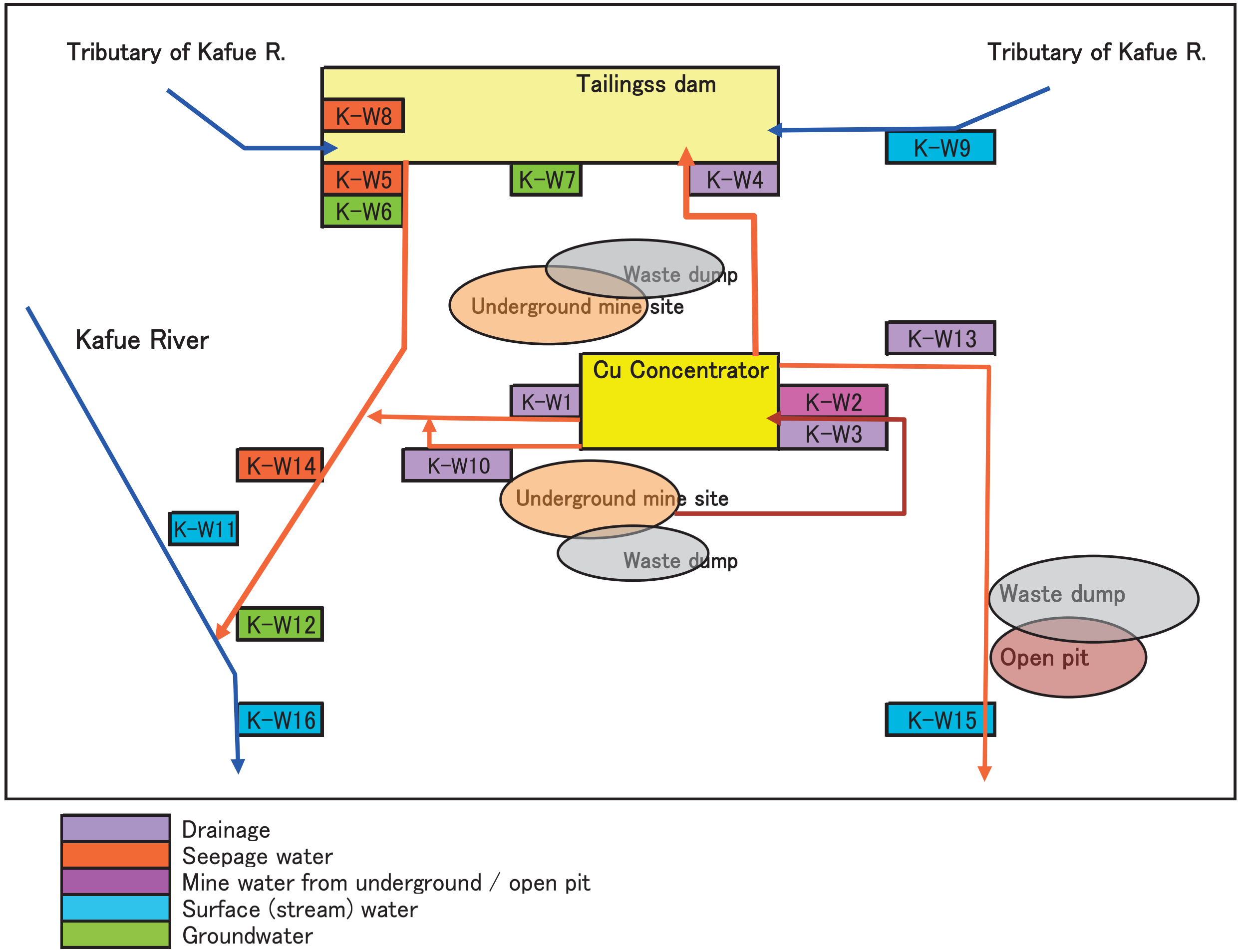
* unknown: Concentrate value could not be detected due to abnormal reaction colour.

Drainage
Seepage water
Mine water from underground / open pit
Surface (stream) water
Groundwater



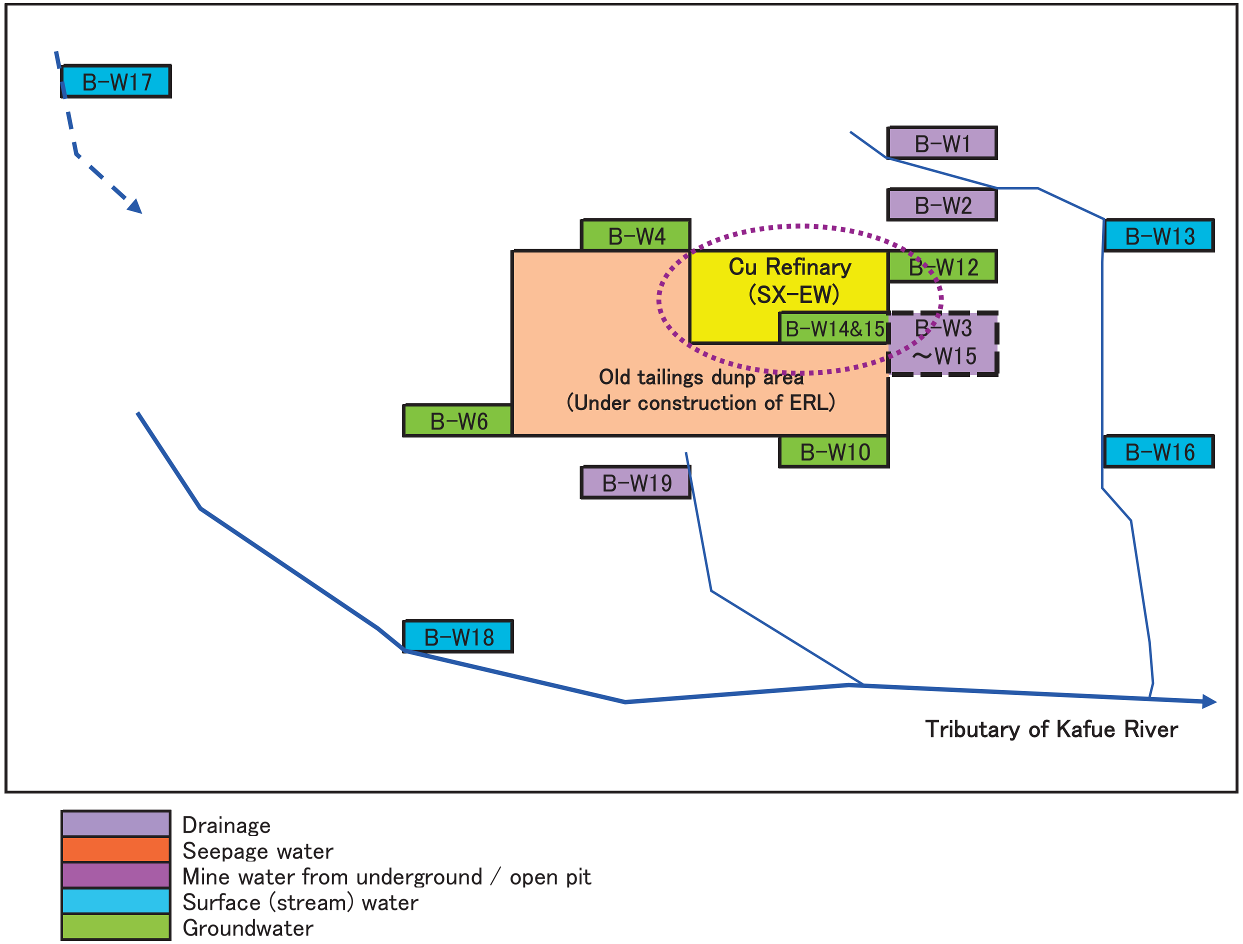
No.	Remarks
M-W2	Northeast of mine site
M-W5	Upper stream of mine site of MCM
M-W4	Mine water of underground
M-W9	Small pond in Waste rock dump #17
M-W10	Groundwater level : −22.60m, Hole depth : 25.0m
M-W1	Containing drainage water from plantsite of MCM
M-W3	Final spillway of TD11
M-W6	Seepage at TD11
M-W7	Meet point between diversion and past Mufulira River
M-W11	Groundwater level : −2.49m, Hole depth : 18.56m
M-W8	Water intake facility of Kafue River

Figure 4.6 (1) Flow of Water in Mopani Mine Site



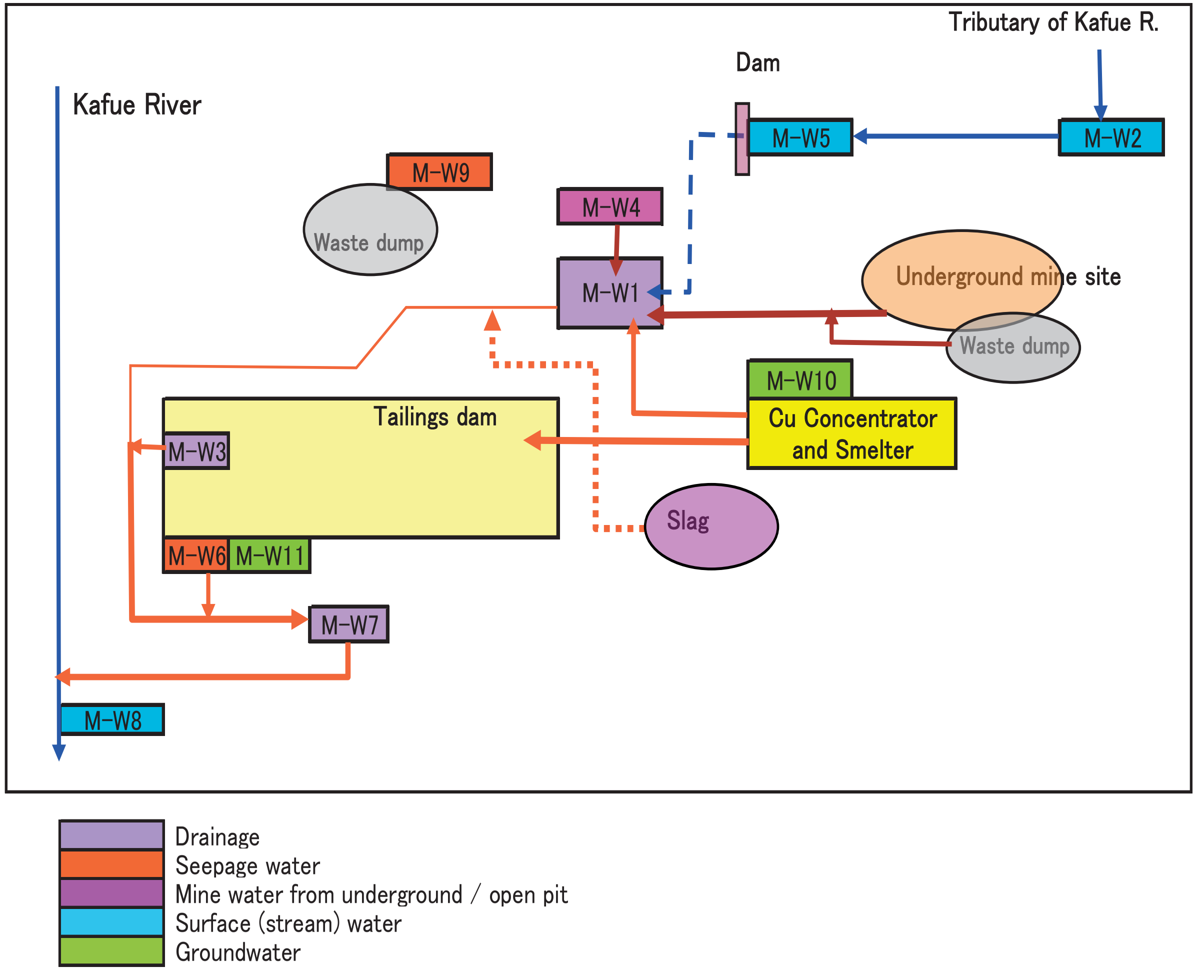
No.	Remarks
K-W9	River at southeast of tailingss dam
K-W1	Drainage water from Concentrator of KCM
K-W2	Mine water of underground of KCM
K-W3	Drainage from underground (main)
K-W4	Drainage from concentrator
K-W10	Drainage from mine facilities
K-W8	Water intake in tailings dam
K-W5	Spillway of tailings dam
K-W6	Groundwater level : −1.68m
K-W7	Groundwater level : −1.00m
K-W14	Combined drainage of spill and seepage at tailings dam
K-W11	Kafue Raw Water Intake
K-W12	Groundwater level : −4.13m
K-W16	Main stream of Kafue River
K-W13	Combined drainage of concentrator and underground
K-W15	South of mine site

Figure 4.6 (2) Flow of Water in Konkola Mine Site



No.	Remarks
B-W17	Uppermost location in the site
B-W18	At culvert bridge along the main road
B-W1	Drainage from Plant site of Kabwe Mine
B-W2	Drainage from Plant site of Kabwe Mine
B-W3	Drainage from Plant site of Kabwe Mine
B-W4	Groundwater level : -several m
B-W5	Small pond in mixture of tailings and slag
B-W6	Groundwater level : -several m
B-W7	Pond for reutilization of Cu leaching
B-W8	Cu-oxides are generated in the drainage
B-W9	Combined wetland of seepage and natural water
B-W10	Assembled Cu seeped water
B-W11	Recirculated leached water intake at plant site
B-W12	Groundwater level : -several m
B-W14	Shallow groundwater at shaft
B-W15	Relatively deeper groundwater at shaft
B-W19	Water is likely same as B-W8 (?).
B-W13	Stream from east of mine site
B-W16	At bridge, terbidity (and SS) is very high and water colour is light brown.

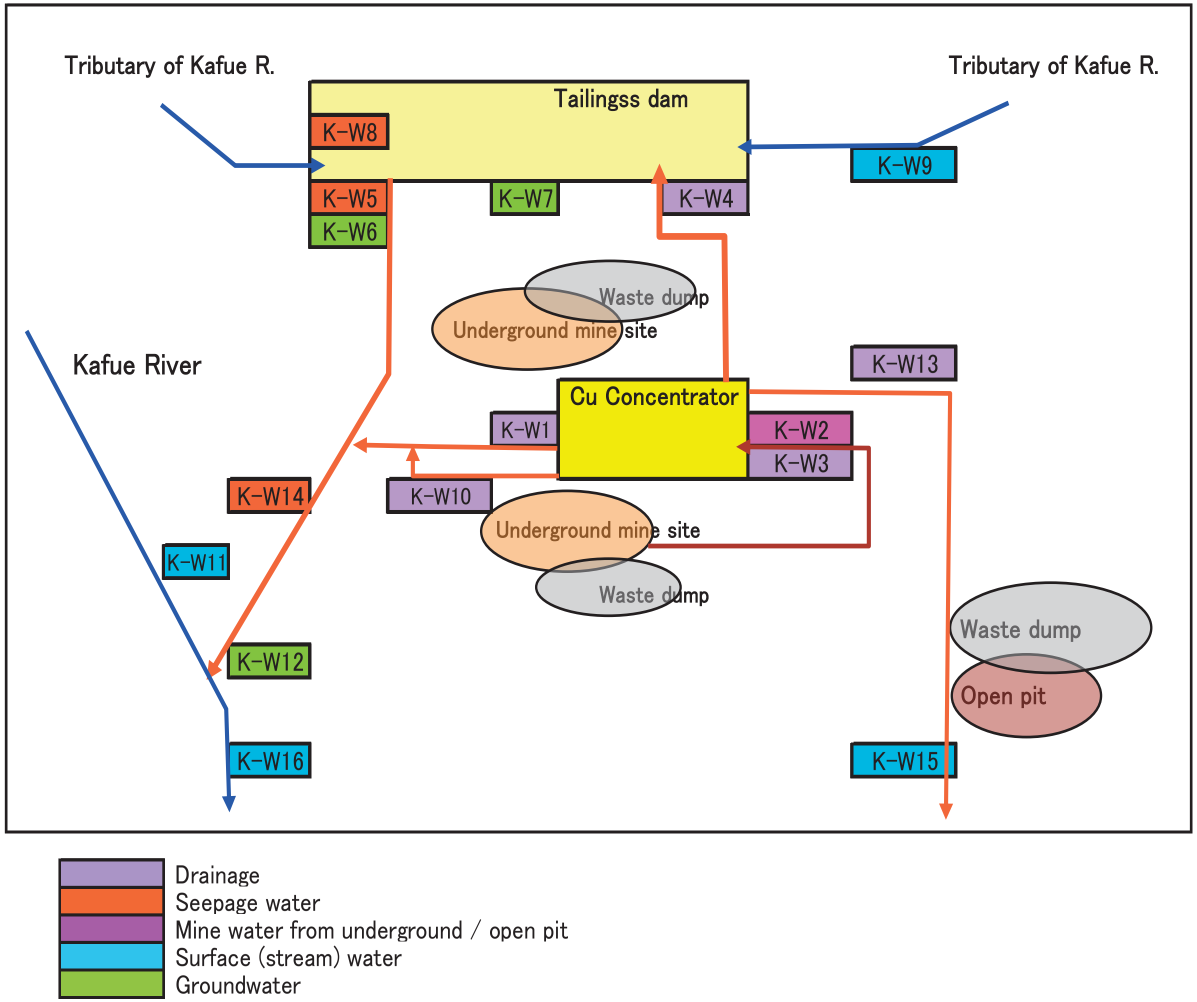
Figure 4.6 (3)　Flow of Water in Kabwe Mine Site



PT	EC (mS/m)	pH	degree C.	T-Cr	Mn	Cu	Zn	T-Metals	Ni	SN	F
M-W2	5	6.56	23.8	<0.5	<0.5	<0.5	0.1	0.2	<0.3	non	0.1
M-W5	11	8.15	27.0	<0.5	<0.5	<0.5	0.02	0.2	<0.3	non	non
M-W4	85	8.46	31.8	<0.5	<0.5	1.5	0.5	0.5	<0.3	non	non
M-W9	205	8.70	28.1	<0.5	<0.5	<0.5	0.5	0.1	<0.3	non	non
M-W10	199	6.70	28.7	<0.5	<0.5	<0.5	0.3	0.2	<0.3	non	non
M-W1	90	7.72	26.5	<0.5	<0.5	0.5	0.5	0.2	<0.3	non	non
M-W3	231	8.15	28.8	<0.5	1.5	<0.5	1.5	3.0	<0.3	non	0.8
M-W6	254	6.60	24.1	<0.5	2.0	<0.5	>2	>5	<0.3	non	non
M-W7	113	7.46	25.4	<0.5	<0.5	<0.5	1.0	1.0	<0.3	non	non
M-W11	93	7.77	25.3	<0.5	0.5	<0.5	>2	0.5	<0.3	non	non
M-W8	23	7.62	25.3	<0.5	<0.5	0.5	0.4	0.2	<0.3	non	non

Evaluation
- Very high concentration (electric conductibity)
- High
- Moderate
- Low
- Very low

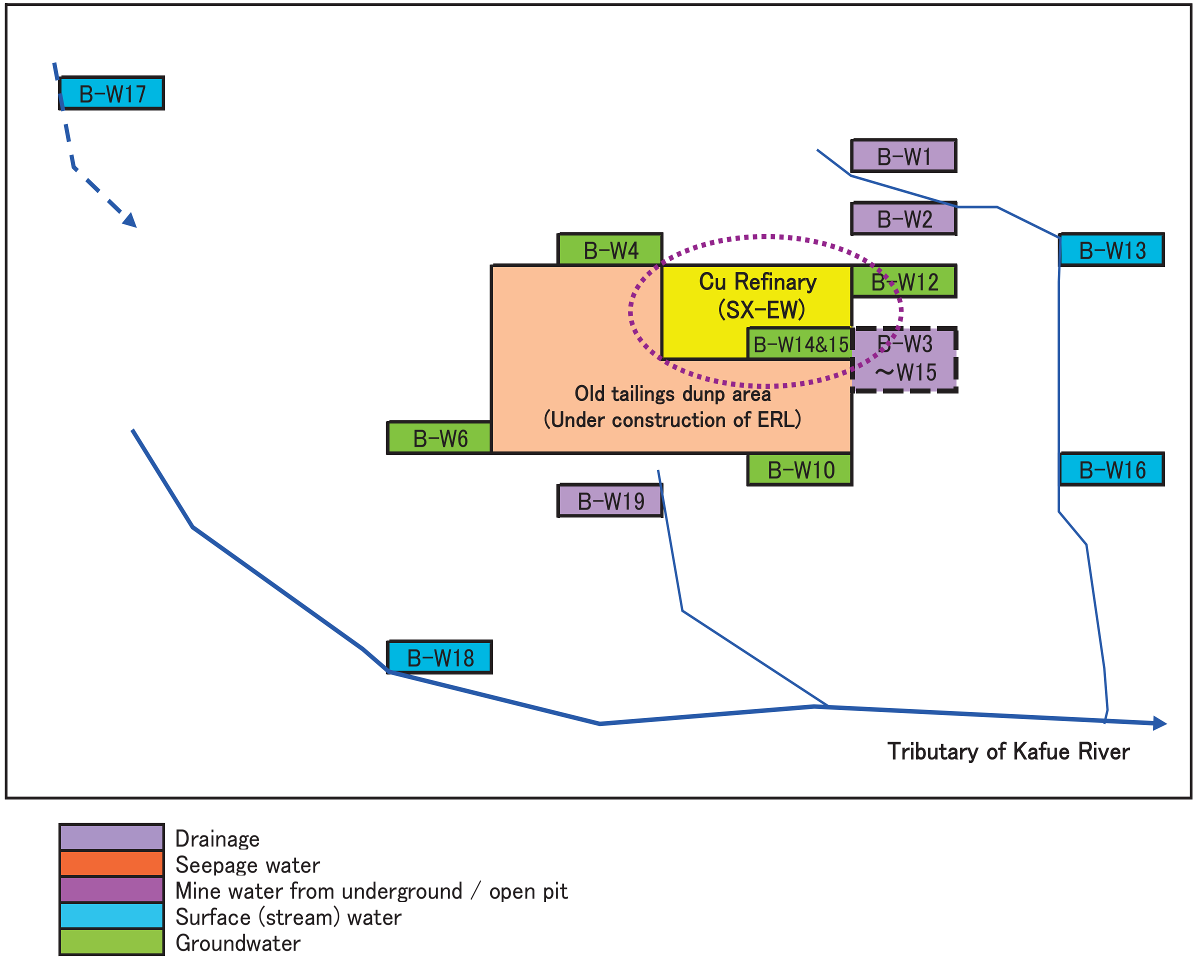
Figure 4.7 (1) Contamination Conditions in Mopani Mine Site (Pack Test)



PT	EC (mS/m)	pH	degree C.	T-Cr	Mn	Cu	Zn	T-Metals	Ni	SN	F
K-W9	22	6.19	22.7	<0.5	<0.5	<0.5	0.2	0.2	<0.3	non	non
K-W1	46	8.49	27.7	<0.5	<0.5	0.5	0.5	0.4	<0.3	non	0.4
K-W2	48	8.15	28.6	<0.5	<0.5	<0.5	1.0	0.5	<0.3	non	non
K-W3	48	8.06	27.8	<0.5	<0.5	0.5	0.5	0.5	<0.3	non	non
K-W4	49	8.53	29.4	<0.5	<0.5	0.5	0.2	0.5	<0.3	non	0.4
K-W10	52	8.39	24.9	<0.5	<0.5	0.5	0.5	0.5	<0.3	non	non
K-W8	31	7.94	24.1	<0.5	<0.5	<0.5	0.05	0.2	<0.3	non	non
K-W5	30	8.58	25.2	<0.5	<0.5	<0.5	0.1	0.1	<0.3	non	non
K-W6	2	5.32	24.3	<0.5	<0.5	<0.5	0.2	0.1	<0.3	non	non
K-W7	34	6.13	23.2	<0.5	<0.5	<0.5	0.1	0.2	<0.3	non	non
K-W14	30	8.04	24.6	<0.5	<0.5	<0.5	0.1	0.1	<0.3	non	non
K-W11	13	7.30	25.4	<0.5	<0.5	<0.5	0.05	0.1	<0.3	non	non
K-W12	11	5.41	22.5	<0.5	<0.5	0.5	0.05	0.2	<0.3	non	non
K-W16	15	7.30	25.4	<0.5	<0.5	<0.5	0.1	0.2	<0.3	non	non
K-W13	49	8.11	27.2	<0.5	<0.5	0.5	0.5	0.5	<0.3	non	non
K-W15	6	7.18	22.2	<0.5	<0.5	<0.5	0.2	0.2	<0.3	non	non

Evaluation
- Very high concentration (electric conductibity)
- High
- Moderate
- Low
- Very low

Figure 4.7 (2) Contamination Conditions in Konkola Mine Site (Pack Test)



PT	EC (mS/m)	pH	degree C.	T-Cr	Mn	Cu	Zn	T-Metals	Ni	SN	F
B-W17	5	7.15	25.5	<0.5	1.0	0.5	0.2	0.5	<0.3	non	0.4
B-W18	26	6.97	23.5	<0.5	1.0	0.5	>2	3.5	<0.3	non	non
B-W1	35	9.08	27.6	<0.5	<0.5	<0.5	0.5	0.5	<0.3	non	non
B-W2	24	8.02	25.9	<0.5	<0.5	<0.5	0.35	0.5	<0.3	non	non
B-W3	30	8.41	29.5	<0.5	0.75	0.5	1.5	1.5	<0.3	non	0.4
B-W4	52	7.00	24.5	<0.5	<0.5	<0.5	>2	1.5	<0.3	non	0.4
B-W5	53	6.62	21.4	<0.5	2.0	1.5	>2	>5	<0.3	non	0.8
B-W6	31	7.61	24.8	<0.5	2.5	<0.5	>2	3.5	<0.3	non	non
B-W7	904	3.25	23.1	<0.5	nknow	1.5	>2	>5	<0.3	nknow	0.4
B-W8	477	6.35	25.2	<0.5	nknow	>10	>2	>5	<0.3	non	non
B-W9	378	6.39	23.4	<0.5	8.0	>10	>2	>5	<0.3	non	0.4
B-W10	260	7.18	24.7	<0.5	8.0	0.8	>2	>5	<0.3	non	0.4
B-W11	191	6.41	25.1	<0.5	15.0	>10	>2	>5	<0.3	non	0.2
B-W12	215	6.51	25.5	<0.5	2.0	0.5	>2	>5	<0.3	non	0.2
B-W14	62	8.35	24.4	<0.5	<0.5	<0.5	0.5	0.5	<0.3	non	non
B-W15	85	7.76	24.9	<0.5	<0.5	<0.5	2.0	1.5	<0.3	non	non
B-W19	198	6.83	26.0	<0.5	2.0	1.5	>2	>5	<0.3	non	0.4
B-W13	112	7.90	25.6	<0.5	2.0	1.0	>2	>5	<0.3	non	0.4
B-W16	90	7.16	22.9	nknow	nknow	nknow	>2	>5	nknow	nknow	non

Evaluation
- Very high concentration (electric conductibity)
- High
- Moderate
- Low
- Very low

Figure 4.7 (3) Contamination Conditions in Kabwe Mine Site (Pack Test)

4.4.6 Analytical Results of Water

Chemical analytical results of water in each mine site are shown in Table 4.11. Water quality is evaluated by the Zambian Effluent Standard and Japanese Environmental Standard for Water as reference. Evaluation results and distribution of relatively high concentration zones of harmful metals are shown in Figure 4.8 (1), (2) and (3).

Table.11 Result of Water Quality Analysis

Items	EC	pH	As	Cd	Cr	Cu	Pb	Se	Zn	CN-	F	SO4
No.	mS/m		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
M-W1	90	7.72	< 0.02	< 0.001	< 0.001	0.15	< 0.01	< 0.02	0.017	< 0.05	0.14	350
M-W2	5	6.56	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.04	21
M-W3	231	8.15	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	2.6	1300
M-W4	85	8.46	< 0.02	< 0.001	< 0.001	0.07	< 0.01	< 0.02	0.026	< 0.05	0.21	917
M-W5	11	8.15	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.07	8.0
M-W6	254	6.60	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.09	1600
M-W7	113	7.46	< 0.02	< 0.001	< 0.001	0.03	< 0.01	< 0.02	< 0.006	< 0.05	0.84	614
M-W8	23	7.62	< 0.02	< 0.001	< 0.001	0.14	< 0.01	< 0.02	< 0.006	< 0.05	0.13	49
M-W9	205	8.70	< 0.02	< 0.001	< 0.001	0.04	< 0.01	< 0.02	< 0.006	< 0.05	0.16	1400
M-W10	199	6.70	< 0.02	< 0.001	< 0.001	0.04	< 0.01	< 0.02	< 0.006	< 0.05	0.17	1100
M-W11	93	7.77	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.3	< 0.05	0.04	430
K-W1	46	8.49	< 0.02	< 0.001	< 0.001	0.09	< 0.01	< 0.02	< 0.006	< 0.05	0.11	74
K-W2	48	8.15	< 0.02	< 0.001	< 0.001	0.18	< 0.01	< 0.02	0.007	< 0.05	0.11	110
K-W3	48	8.06	< 0.02	< 0.001	< 0.001	0.16	< 0.01	< 0.02	0.008	< 0.05	0.13	100
K-W4	49	8.53	< 0.02	< 0.001	< 0.001	0.02	< 0.01	< 0.02	< 0.006	< 0.05	0.25	130
K-W5	30	8.58	< 0.02	< 0.001	< 0.001	0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.06	60
K-W6	2	5.32	< 0.02	< 0.001	< 0.001	0.06	< 0.01	< 0.02	0.017	< 0.05	0.13	10
K-W7	34	6.13	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.009	< 0.05	0.06	9.0
K-W8	31	7.94	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.04	50
K-W9	22	6.19	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.12	12
K-W10	52	8.39	< 0.02	< 0.001	< 0.001	0.09	< 0.01	< 0.02	0.027	< 0.05	0.12	160
K-W11	13	7.30	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.06	14
K-W12	11	5.41	< 0.02	< 0.001	< 0.001	0.02	< 0.01	< 0.02	0.006	< 0.05	0.04	7.0
K-W13	49	8.11	< 0.02	< 0.001	< 0.001	0.13	< 0.01	< 0.02	0.006	< 0.05	0.08	100
K-W14	30	8.04	< 0.02	< 0.001	< 0.001	0.02	< 0.01	< 0.02	< 0.006	< 0.05	0.14	35
K-W15	6	7.18	< 0.02	< 0.001	< 0.001	0.03	< 0.01	< 0.02	< 0.006	< 0.05	0.06	12
K-W16	15	7.30	< 0.02	< 0.001	< 0.001	0.04	< 0.01	< 0.02	< 0.006	< 0.05	0.06	10
B-W1	35	9.08	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.2	< 0.05	0.24	10
B-W2	24	8.02	< 0.02	< 0.001	< 0.001	0.03	0.03	< 0.02	0.063	< 0.05	0.19	9.0
B-W3	30	8.41	< 0.02	0.001	< 0.001	0.10	0.21	< 0.02	0.20	< 0.05	0.56	12
B-W4	52	7.00	< 0.02	0.003	< 0.001	0.03	0.01	0.02	1.5	< 0.05	0.14	400
B-W5	53	6.62	< 0.02	0.16	< 0.001	0.82	0.72	< 0.02	34	< 0.05	0.21	570
B-W6	31	7.61	< 0.02	< 0.001	< 0.001	0.05	0.01	< 0.02	0.12	< 0.05	0.36	89
B-W7	904	3.25	0.23	0.032	0.065	840	0.46	0.04	21	< 0.05	2.0	6900
B-W8	477	6.35	0.03	0.13	< 0.001	63	0.34	0.04	180	< 0.05	0.44	7100
B-W9	378	6.39	< 0.02	0.080	< 0.001	16	0.47	< 0.02	9.4	< 0.05	0.14	400
B-W10	260	7.18	< 0.02	0.023	< 0.001	0.22	0.11	0.02	2.4	< 0.05	5.9	2700
B-W11	191	6.41	< 0.02	0.040	< 0.001	35	0.28	< 0.02	1.7	< 0.05	0.32	940
B-W12	215	6.51	< 0.02	0.076	< 0.001	0.28	0.08	0.04	2.8	< 0.05	0.19	1000
B-W13	112	7.90	< 0.02	0.010	< 0.001	0.92	0.09	< 0.02	1.9	< 0.05	0.74	430
B-W14	62	8.35	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.67	< 0.05	0.12	190
B-W15	85	7.76	< 0.02	0.004	< 0.001	< 0.01	< 0.01	< 0.02	1.1	< 0.05	0.17	200
B-W16	90	7.16	< 0.02	0.015	< 0.001	< 0.01	< 0.01	< 0.02	1.7	< 0.05	0.15	250
B-W17	5	7.15	< 0.02	< 0.001	0.005	< 0.01	< 0.01	< 0.02	0.036	< 0.05	0.09	50
B-W18	26	6.97	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.025	< 0.05	0.09	7.0
B-W19	198	6.83	< 0.02	0.014	< 0.001	0.89	0.01	< 0.02	28	< 0.05	0.10	1100

(1) Mopani Mine Site

The concentration of F and SO_4^{-2} are beyond the Effluent Standard. The concentration of F in the discharged water from the tailings dam is 2.6 mg/L being higher than Effluent Standard (2 mg/L). And the concentration of SO_4^{-2} is also 1600 mg/L showing to be exceeded Effluent Standard (1500 mg/L). The concentration of other components is less than the Effluent Standard. In case of comparison of Japanese Environmental Standard for Water as reference, only F is beyond the standard.

Components being relatively high concentration of metals in and outside of the mine site shows Zn, Cu and F. Zu shows to be relatively high concentration in the seeped water from the tailings dam. Cu shows to be relatively high concentration in the seeped water from the Concentrator, mine water, waste dump area and drainage water from the tailings dam. F to be relatively high concentration in the drainage water from the tailings dam and Concentrator.

(Correlation between components)
Correlation between components at Mopani mine site is shown in Table 4.12.

Table 4.12 Correlation in Elution Components at Mopani Mine Site

Items	Cu	Zn	F	SO_4^{-2}
Cu	1.000	-	-	-
Zn	-0.211	1.000	-	-
F	-0.234	-0.172	1.000	-
SO_4^{-2}	-0.291	-0.159	0.345	1.000

* Component: the calculation was excepted under the determination limit.

(2) Konkola Mine Site

Drainage and river water in the Konkola mine site is less than the concentration of the Effluent Standard. And the component to be relatively high concentration in the mine site is only Cu in the drainage water from the Concentrator.

(Correlation between components)
Correlation between components at Konkola mine site is shown in Table 4.13.

Table 4.13 Correlation in Elution Components at Konkola Mine Site

	Cu	Zn	F	SO_4^{-2}
Cu	1.000	-	-	-
Zn	0.310	1.000	-	-
F	0.191	0.137	1.000	-
SO_4^{-2}	0.611	0.401	0.534	1.000

* Component: the calculation was excepted under the determination limit.

(3) Kabwe Mine Site

Although discharged water of BW-3 to B-W15 within the Kabwe mine site is exceeded the Effluent Standard of Cu, Zn, Pb and SO_4^{-2}, almost of discharged water is recovered and recycled in the Cu Smelter's process.

In the old mine site and around the Cu Smelter, all of components except Zn show less than the Effluent Standard. Zn concentration of B-W19 shows 28 mg/L, exceeding the Effluent Standard. And the components of relatively high concentration in and outside of the mine site consist of Zn, Pb and Cd, therefore these components are widely diffused to the downstream.

(Correlation between components)

Correlation between components at Kabwe mine site is shown in Table 4.14.

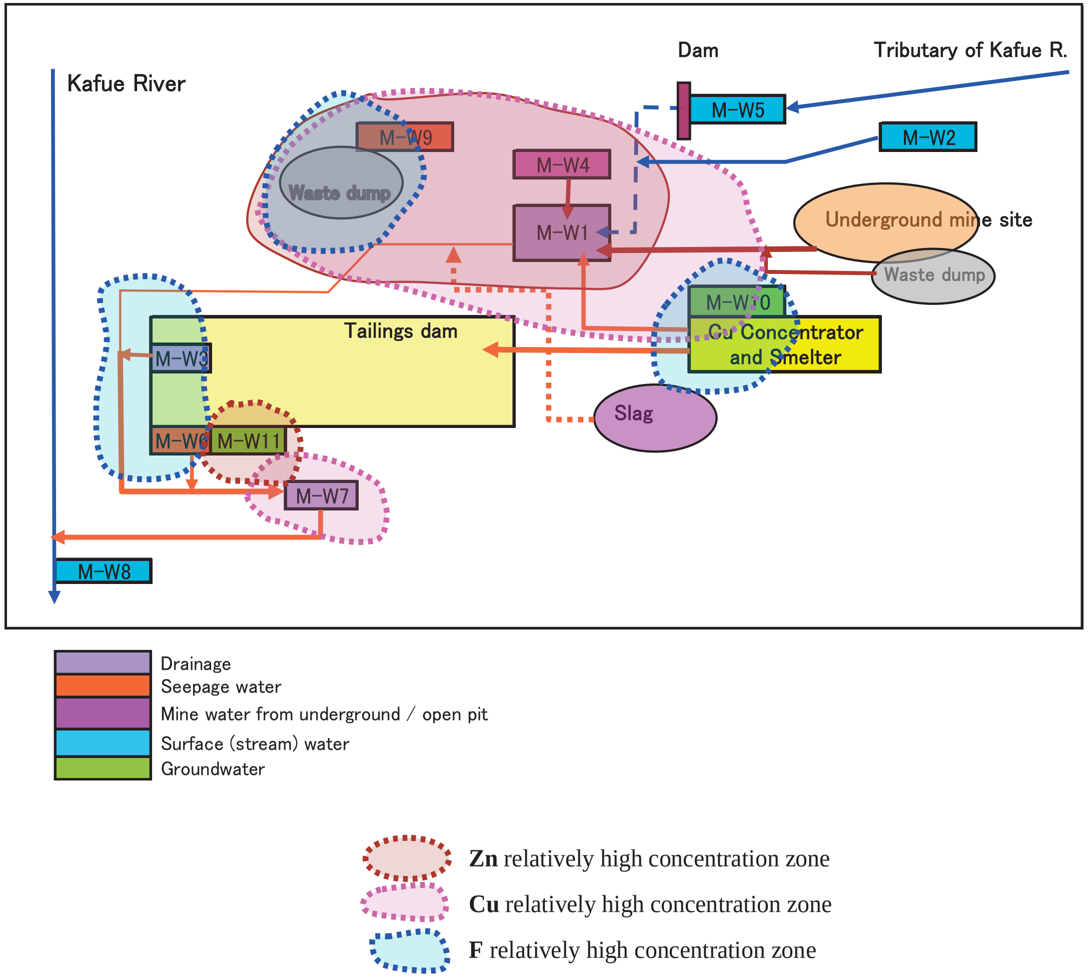
Table 4.14 Correlation in Elution Components at Kabwe Mine Site

	Cd	Cu	Pb	Zn	F	SO_4^{-2}
Cd	1.000	-	-	-	-	-
Cu	0.052	1.000	-	-	-	-
Pb	0.808	0.390	1.000	-	-	-
Zn	0.645	0.106	0.377	1.000	-	-
F	-0.030	0.235	0.081	-0.033	1.000	-
SO_4^{-2}	0.435	0.695	0.436	0.724	0.379	1.000

* Component: the calculation was excepted under the determination limit.

(4) Summary

- Evaluation results by the Zambian Effluent Standard, the drainage water shows that the concentration of F and SO_4^{-2} is exceeded the Effluent Standard.
- In the Konkola mine site, all of concentration of components are less than the Effluent Standard.
- Outside of the Kabwe mine site, all of concentration of components are less than the Effluent Standard.
- Consequently, the water pollution of F and SO_4^{-2} is recognized in the Mopani mine site. However, the water pollution is not recognized in the Konkola and outside of the Kabwe mine sites.
- In case of evaluation by the Japanese Environmental Standard for water, water pollutions of F in the Mopani mine site and Cd, Pb and Zn outside of the Kabwe mine site.



PT	EC (mS/m)	pH	As	Cd	Cr	Cu	Pb	Se	Zn	CN−	F	SO_4^{-2}
M-W2	5	6.56	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.04	21
M-W5	11	8.15	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.07	8.0
M-W4	85	8.46	< 0.02	< 0.001	< 0.001	0.07	< 0.01	< 0.02	0.026	< 0.05	0.21	917
M-W9	205	8.70	< 0.02	< 0.001	< 0.001	0.04	< 0.01	< 0.02	< 0.006	< 0.05	0.16	1400
M-W10	199	6.70	< 0.02	< 0.001	< 0.001	0.04	< 0.01	< 0.02	< 0.006	< 0.05	0.17	1100
M-W1	90	7.72	< 0.02	< 0.001	< 0.001	0.15	< 0.01	< 0.02	0.017	< 0.05	0.14	350
M-W3	231	8.15	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	2.6	1300
M-W6	254	6.60	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.09	1600
M-W7	113	7.46	< 0.02	< 0.001	< 0.001	0.03	< 0.01	< 0.02	< 0.006	< 0.05	0.84	614
M-W11	93	7.77	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.34	< 0.05	0.04	430
M-W8	23	7.62	< 0.02	< 0.001	< 0.001	0.14	< 0.01	< 0.02	< 0.006	< 0.05	0.13	49

Evaluation

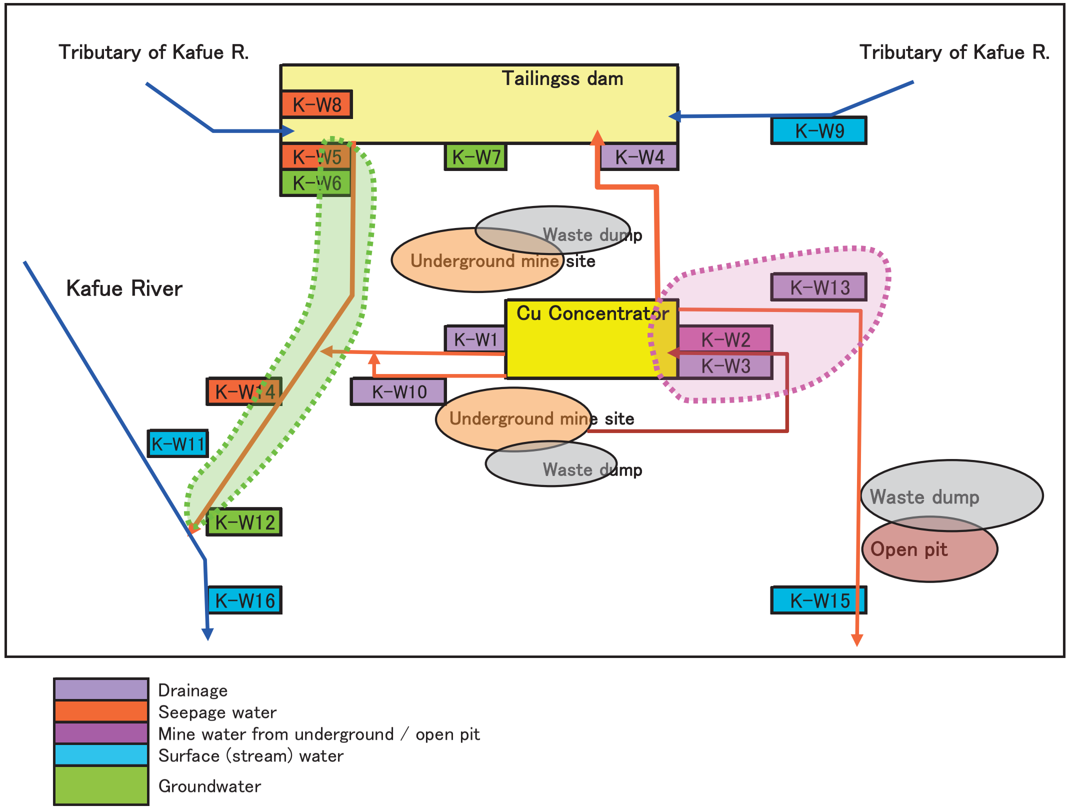
- Very high concentration (>=(ES−1)*10)
- High (>=(ES−1)*5, <(ES−1)*10)
- Moderate (>ES−1, < (ES−1)*5)
- Low (<ES−1, >ES−2)
- Very low

	EC	pH	As	Cd	Cr	Cu	Pb	Se	Zn	CN−	F	SO_4^{-2}
ES-1	−	6 − 9	0.05	0.5	0.1	1.5	0.5	0.02	10	0.2	2	1500
ES-2	−	8.5	0.01	0.01	0.05	3	0.01	0.01	5	0.01	0.8	−

*ES-1 : Effuluent Standard in Zambia

*ES-2 : Environmental Standard in Japan

Figure 4.8 (1) Relatively High Concentration Area of Zn, Cu and F at Mopani Mine Site



PT	EC (mS/m)	pH	As	Cd	Cr	Cu	Pb	Se	Zn	CN⁻	F	SO_4^{-2}
K-W9	22	6.19	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.12	12
K-W1	46	8.49	< 0.02	< 0.001	< 0.001	0.09	< 0.01	< 0.02	< 0.006	< 0.05	0.11	74
K-W2	48	8.15	< 0.02	< 0.001	< 0.001	0.18	< 0.01	< 0.02	0.007	< 0.05	0.11	110
K-W3	48	8.06	< 0.02	< 0.001	< 0.001	0.16	< 0.01	< 0.02	0.008	< 0.05	0.13	100
K-W4	49	8.53	< 0.02	< 0.001	< 0.001	0.02	< 0.01	< 0.02	< 0.006	< 0.05	0.25	130
K-W10	52	8.39	< 0.02	< 0.001	< 0.001	0.09	< 0.01	< 0.02	0.027	< 0.05	0.12	160
K-W8	31	7.94	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.04	50
K-W5	30	8.58	< 0.02	< 0.001	< 0.001	0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.06	60
K-W6	2	5.32	< 0.02	< 0.001	< 0.001	0.06	< 0.01	< 0.02	0.017	< 0.05	0.13	10
K-W7	34	6.13	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.009	< 0.05	0.06	9.0
K-W14	30	8.04	< 0.02	< 0.001	< 0.001	0.02	< 0.01	< 0.02	< 0.006	< 0.05	0.14	35
K-W11	13	7.30	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	< 0.006	< 0.05	0.06	14
K-W12	11	5.41	< 0.02	< 0.001	< 0.001	0.02	< 0.01	< 0.02	0.006	< 0.05	0.04	7.0
K-W16	15	7.30	< 0.02	< 0.001	< 0.001	0.04	< 0.01	< 0.02	< 0.006	< 0.05	0.06	10
K-W13	49	8.11	< 0.02	< 0.001	< 0.001	0.13	< 0.01	< 0.02	0.006	< 0.05	0.08	100
K-W15	6	7.18	< 0.02	< 0.001	< 0.001	0.03	< 0.01	< 0.02	< 0.006	< 0.05	0.06	12

Evaluation
- Very high concentration (>=(ES-1)*10)
- High (>=(ES-1)*5, <(ES-1)*10)
- Moderate (>ES-1, < (ES-1)*5)
- Low (<ES-1, >ES-2)
- Very low

	EC	pH	As	Cd	Cr	Cu	Pb	Se	Zn	CN-	F	SO_4^{-2}
ES-1	-	6 - 9	0.05	0.5	0.1	1.5	0.5	0.02	10	0.2	2	1500
ES-2	-	8.5	0.01	0.01	0.05	3	0.01	0.01	5	0.01	0.8	-

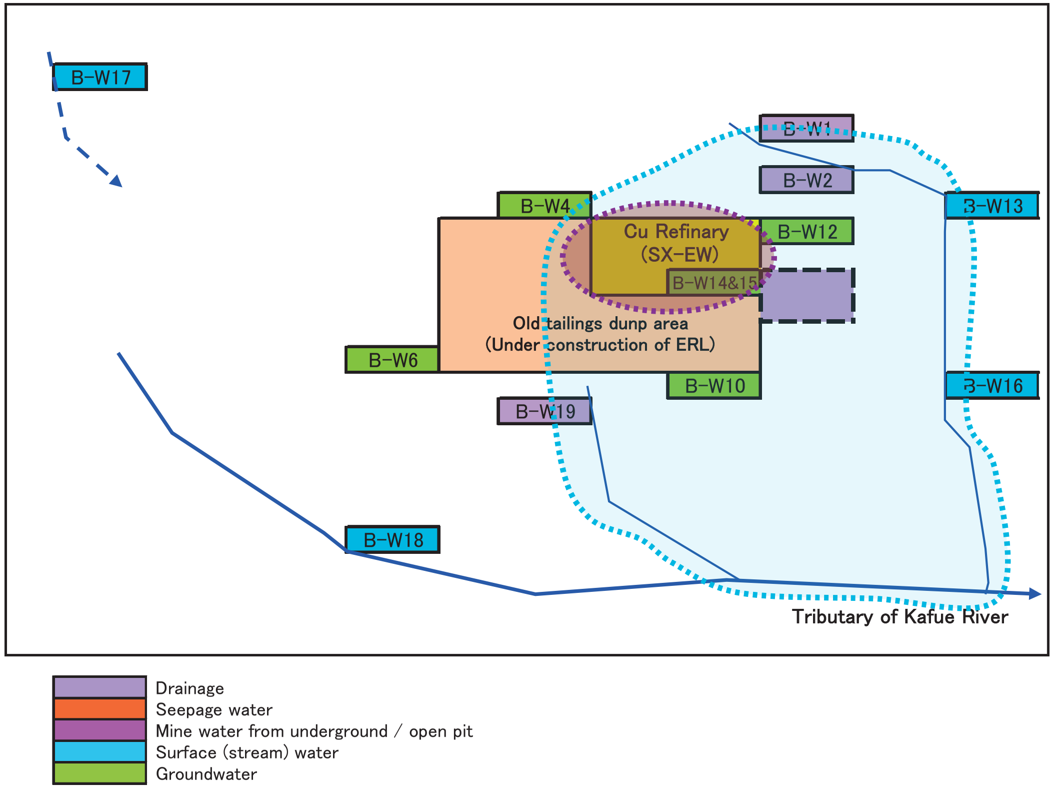
*ES-1 : Effuluent Standard in Zambia

*ES-2 : Environmental Standard in Japan

Zn relatively high concentration zone

Acidic groundwater zone

Figure 4.8 (2) Relatively High Concentration Area of Zn and the Distribution of Acid Water at Konkola Mine Site



PT	EC (mS/m)	pH	As	Cd	Cr	Cu	Pb	Se	Zn	CN^-	F	SO_4^{-2}
B-W17	5	7.15	< 0.02	< 0.001	0.005	< 0.01	< 0.01	< 0.02	0.036	< 0.05	0.09	50
B-W18	26	6.97	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.025	< 0.05	0.09	7.0
B-W1	35	9.08	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.19	< 0.05	0.24	10
B-W2	24	8.02	< 0.02	< 0.001	< 0.001	0.03	0.03	< 0.02	0.063	< 0.05	0.19	9.0
B-W3	30	8.41	< 0.02	0.001	< 0.001	0.10	0.21	< 0.02	0.20	< 0.05	0.56	12
B-W4	52	7.00	< 0.02	0.003	< 0.001	0.03	0.01	0.02	1.5	< 0.05	0.14	400
B-W5	53	6.62	< 0.02	0.16	< 0.001	0.82	0.72	< 0.02	34	< 0.05	0.21	570
B-W6	31	7.61	< 0.02	< 0.001	< 0.001	0.05	0.01	< 0.02	0.12	< 0.05	0.36	89
B-W7	904	3.25	0.23	0.032	0.065	840	0.46	0.04	21	< 0.05	2.0	6900
B-W8	477	6.35	0.03	0.13	< 0.001	63	0.34	0.04	180	< 0.05	0.44	7100
B-W9	378	6.39	< 0.02	0.080	< 0.001	16	0.47	< 0.02	9.4	< 0.05	0.14	400
B-W10	260	7.18	< 0.02	0.023	< 0.001	0.22	0.11	0.02	2.4	< 0.05	5.9	2700
B-W11	191	6.41	< 0.02	0.040	< 0.001	35	0.28	< 0.02	1.7	< 0.05	0.32	940
B-W12	215	6.51	< 0.02	0.076	< 0.001	0.28	0.08	0.04	2.8	< 0.05	0.19	1000
B-W14	62	8.35	< 0.02	< 0.001	< 0.001	< 0.01	< 0.01	< 0.02	0.67	< 0.05	0.12	190
B-W15	85	7.76	< 0.02	0.004	< 0.001	< 0.01	< 0.01	< 0.02	1.1	< 0.05	0.17	200
B-W19	198	6.83	< 0.02	0.014	< 0.001	0.89	0.01	< 0.02	28	< 0.05	0.10	1100
B-W13	112	7.90	< 0.02	0.010	< 0.001	0.92	0.09	< 0.02	1.9	< 0.05	0.74	430
B-W16	90	7.16	< 0.02	0.015	< 0.001	< 0.01	< 0.01	< 0.02	1.7	< 0.05	0.15	250

Evaluation
- Very high concentration (>=(ES−1)*10)
- High (>=(ES−1)*5, <(ES−1)*10)
- Moderate (>ES−1, < (ES−1)*5)
- Low (<ES−1, >ES−2)
- Very low

	EC	pH	As	Cd	Cr	Cu	Pb	Se	Zn	CN^-	F	SO_4^{-2}
ES−1	−	6 − 9	0.05	0.5	0.1	1.5	0.5	0.02	10	0.2	2	1500
ES−2	−	6.5 − 8.5	0.01	0.01	0.05	3	0.01	0.01	5	0.01	0.8	−

*ES−1 : Effuluent Standard in Zambia
*ES−2 : Environmental Standard in Japan

Cu polluted zone
Zn, Pb and Cd relatively high concentration zone

Figure 4.8 (3) Relatively High Concentration Area of Cu, Zn, Pb and Cd at Kabwe Mine Site

4.4.7 Results of Physical Test

Soil sampling in the Mopani, Konkola and Kabwe mine sites and physical test were carried out during the site investigation. Results of physical tests of soil, consisting of wet specific gravity, true specific gravity, moisture and grain analysis, are shown in Table 4.15 (1), (2) and (3).

Table 4.15 Results of Physical Tests of Soil

(1) Mopani Mine Site

Muflina mine site

Sample No.	Wet Specific Gravity	Moisture	True Specific Gravity	Weight (g) passing Screen (size: microns)												
				25000	19000	9500	4760	2000	850	500	250	106	75	45	-45	Total Wt (g)
M-S1	1.56	13.80	2.58	0.0	0.0	0.0	0.9	11.0	33.0	34.5	60.7	74.9	20.4	26.2	38.2	299.8
M-S2	2.03	13.14	2.59	0.0	0.0	0.0	0.0	3.6	4.1	54.7	70.0	61.8	19.1	12.2	71.6	297.1
M-S3	1.73	18.90	2.71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.1	52.7	70.6	86.3	77.4	299.1
M-S4	1.68	18.78	2.57	0.0	0.0	8.3	6.3	7.8	9.5	18.4	52.8	86.9	33.0	0.6	74.8	298.4
M-S5	2.31	13.12	2.62	0.0	0.0	0.0	10.7	19.1	50.5	23.7	30.8	63.9	32.5	27.1	40.1	298.4
M-S6	2.00	15.37	2.7	0.0	0.0	8.0	23.8	23.9	8.7	7.0	20.4	63.9	47.5	55.5	40.5	299.2
M-S7	1.29	32.38	2.56	0.0	0.0	19.2	15.2	12.5	14.7	18.8	30.1	37.5	23.8	35.0	91.0	297.8
M-S8	2.33	1.52	3.78	0.0	0.0	0.0	0.0	15.1	117.1	98.6	47.2	13.6	2.4	0.2	4.8	299.0
M-S9	1.39	6.82	2.66	0.0	0.0	17.4	45.2	48.3	42.9	31.7	37.2	35.0	11.0	0.2	30.3	299.2
M-S10	2.18	17.61	2.72	0.0	0.0	0.0	2.0	11.9	29.5	34.7	47.0	83.4	29.6	22.1	38.3	298.5
M-S11	2.30	13.43	2.64	0.0	0.0	1.5	0.8	2.9	39.6	52.3	82.9	66.2	17.1	0.8	35.1	299.2
M-S12	1.93	12.67	2.70	0.0	0.0	0.0	0.9	0.0	0.0	1.0	28.2	148.3	59.5	11.6	50.2	299.7
M-S13	1.65	13.99	2.61	0.0	15.4	17.1	15.8	30.2	21.7	19.6	44.4	46.3	18.9	0.8	68.5	298.7
M-S14	1.96	13.25	2.64	0.0	0.0	0.0	0.0	6.4	32.8	32.6	61.2	75.2	30.0	3.9	56.5	298.6
M-S15	2.47	13.47	2.64	0.0	0.0	15.5	17.9	48.7	87.0	43.8	28.6	24.5	8.9	0.3	23.2	298.4
M-S16	1.89	6.74	2.68	0.0	15.5	27.5	27.1	42.0	47.4	23.7	36.8	44.1	10.9	0.2	19.3	294.5
M-S17	1.75	12.91	2.78	0.0	0.0	7.3	6.0	11.4	12.2	41.8	94.5	15.0	19.0	28.0	60.0	295.2
M-S18	1.74	17.02	2.62	0.0	0.0	0.0	0.0	3.6	9.4	11.9	25.0	80.6	51.9	65.8	51.5	299.7
M-S19	2.02	16.69	2.48	0.0	18.8	0.0	0.6	3.5	9.4	20.3	68.9	104.0	24.9	3.4	40.6	294.4
M-S20	1.64	15.58	2.55	0.0	0.0	0.0	0.5	5.2	41.0	16.5	18.9	117.4	29.0	29.0	41.9	299.4

(2) Konkola Mine Site

Konkola mine site

Sample No.	Wet Specific Gravity	Moisture	True Specific Gravity	Weight (g) passing Screen (size: microns)												
				25000	19000	9500	4760	2000	850	500	250	106	75	45	-45	Total Wt (g)
K-S1	2.16	15.73	2.90	0.0	0.0	0.0	0.0	0.0	0.6	6.4	50.4	122.6	39.0	31.4	48.6	299.0
K-S2	2.16	11.19	2.66	0.0	0.0	0.0	0.5	7.4	17.7	62.6	74.7	75.2	20.2	17.1	23.1	298.5
K-S3	1.73	24.93	2.44	0.0	11.2	53.3	2.2	0.9	20.6	68.5	45.8	36.3	12.8	12.4	33.7	297.7
K-S4	1.64	14.68	2.62	0.0	0.0	0.0	0.0	4.9	26.6	31.1	65.9	99.2	22.0	22.6	26.7	299.0
K-S6	1.95	9.84	-	0.0	43.6	67.2	18.5	20.2	13.5	10.8	17.6	21.5	10.1	20.4	55.6	299.0

(3) Kabwe Mine Site

Kabwe mine site

Sample No.	Wet Specific Gravity	Moisture	True Specific Gravity	Weight (g) passing Screen (size: microns)												
				25000	19000	9500	4760	2000	850	500	250	106	75	45	-45	Total Wt (g)
B-S2	1.85	17.63	2.54	0.0	0.0	0.0	0.9	16.4	45.4	47.2	63.2	63.9	18.8	14.7	27.5	298.0
B-S3	2.61	9.04	2.90	0.0	17.3	69.1	61.4	68.3	35.3	17.1	13.4	7.3	2.1	1.2	7.1	299.6
B-S4	1.28	41.95	3.07	0.0	0.0	0.0	0.0	11.7	67.2	34.4	33.7	29.7	14.1	23.6	82.5	296.9
B-S5	1.66	19.90	2.64	0.0	0.0	9.0	22.6	54.2	32.8	25.8	35.1	50.5	19.8	20.8	27.8	298.4
B-S6	1.63	19.23	2.52	0.0	0.0	0.0	0.4	24.7	89.5	46.9	54.7	46.8	11.8	10.1	13.4	298.3
B-S7	2.30	11.02	3.02	0.0	17.1	45.1	72.7	58.6	37.9	19.3	15.1	9.9	3.9	4.6	15.0	299.2
B-S8	1.59	38.06	3.22	0.0	0.0	5.3	3.0	17.3	65.1	29.8	30.6	34.7	19.0	36.0	57.1	297.9
B-S9	2.33	2.94	-	0.0	0.0	0.0	0.0	18.6	107.7	97.9	58.0	10.7	1.5	1.1	3.7	299.2
B-S10	1.69	12.12	2.62	103.0	0.0	6.3	12.0	17.7	12.5	14.8	38.3	47.0	14.2	14.6	17.6	298.0
B-S11	1.38	21.12	2.52	0.0	0.0	16.5	3.8	14.9	68.0	53.5	62.6	41.8	9.9	7.0	15.3	293.3
B-S12	1.62	17.98	2.51	0.0	0.0	0.0	2.6	16.3	78.0	48.5	62.0	50.5	13.2	11.2	17.8	300.1
B-S13	1.77	17.66	2.51	0.0	0.0	7.7	39.6	86.4	62.0	30.0	27.1	22.0	6.4	6.1	11.8	299.1
B-S14	1.76	16.46	2.49	0.0	0.0	0.0	0.9	26.3	82.4	52.7	61.3	46.7	9.5	7.8	11.6	299.2
B-S15	2.06	17.77	2.72	0.0	28.4	37.6	26.2	32.0	22.9	15.8	23.5	35.6	17.3	21.0	38.6	298.9
B-S16	2.12	16.94	2.59	0.0	9.4	20.3	68.6	57.6	28.5	19.1	25.4	29.1	10.2	10.6	18.4	297.2
B-S17	1.65	18.84	2.56	0.0	0.0	0.0	0.0	0.7	6.6	19.7	43.2	88.0	35.6	43.8	59.9	297.5

showing the maximum value on the weight passed screens..

(1) Wet Specific Gravity

- Wet specific gravity in the Mufulina mine site ranges from 1.29 to 2.47, and M-S15 shows 2.47 as maximum value. The soil is compact.
- Wet specific gravity in the Konkola mine site ranges from 1.64 to 2.16.
- Wet specific gravity in the Kabwe mine site ranges from 1.28 to 2.33, those feature is almost same as Mufulina mine site.

(2) True Specific Gravity

- True specific gravity in the Mufulina mine site ranges from 2.48 to 3.78. Although most of the samples belong to ordinal soil grain, M-S8 (Cu slag) is 3.78 as maximum value that is thought to be contained metal components.
- True specific gravity in the Konkola mine site ranges from 2.44 to 2.90, showing to be ordinal soil grain.
- True specific gravity in the Kabwe mine site ranges from 2.51 to 3.22, showing to be ordinal soil grain.

(3) Moisture Content

- Moisture content in the Mufulina mine site ranges 1.52 to 32.38 %. Moisture content 1.52 is M-S8 (Cu Slag), showing to be minimum value. M-S7 as maximum value is 32.38 %, the soil is rich in silt to clay size. Moisture content of other soil samples range from 12 to 18 ％.
- Moisture content in the Konkola mine site ranges from 9.84 to 24.93 %.
- Moisture content in the Kabwe mine site ranges from 2.94 to 41.95 %, moisture content 2.94 is B-S9 (Cu slag) showing to be minimum value. Moisture content being more than 30 ％ is B-S4 and B-S8, which are mainly composed of silt and clay.

(4) Grain Analysis

Grain features of each soil samples are shown as below.

（**Mufulina Mine Site**）

M-S1: Medium to fine sand predominates.
M-S2: Medium to fine sand and silt to clay predominate.
M-S3: Silt to clay predominates.
M-S4: Medium to fine sand predominates.
M-S5: Sand predominates.
M-S6: Fine sand predominates.
M-S7: Silt to clay predominates.
M-S8: Medium to fine sand predominates.
M-S9: Granule to coarse sand predominates.
M-S10: Fine to very fine sand predominates.
M-S11: Fine to very fine sand predominates.
M-S12: Fine to very fine sand predominates.
M-S13: Silt to clay predominates.
M-S14: Fine to very fine sand and silt to clay predominates.
M-S15: Coarse sand predominates.

M-S16: Coarse to very coarse sand predominates.
M-S17: Medium sand predominates.
M-S18: Fine sand predominates.
M-S19: Medium to fine sand predominates.
M-S20: Coarse sand predominates.

(**Konkola Mine Site**)
K-S1: Coarse sand predominates.
K-S2: Medium to coarse sand predominates.
K-S3: Medium sand predominates.
K-S4: Medium to coarse sand predominates.
K-S6: Silt to clay predominates.

(**Kabwe Mine Site**)
B-S2: Medium to coarse sand predominates.
B-S3: Granule to very coarse sand predominates.
B-S4: Silt to clay predominates.
B-S5: Very coarse sand predominates.
B-S6: Coarse sand predominates.
B-S7: Granule to very coarse sand predominates.
B-S8: Coarse sand predominates.
B-S9: Coarse sand predominates.
B-S10: Gravel predominates.
B-S11: Medium to coarse sand predominates.
B-S12: Medium to coarse sand predominates.
B-S13: Very coarse to coarse sand predominates.
B-S14: Medium to coarse sand predominates.
B-S15: Mostly distribute uniformly, Silt to clay relatively predominates.
B-S16: Granule to very coarse sand predominates.
B-S17: Fine sand predominates.

4.4.8 Results of Chemical Analysis of Soil

Soil samples were collected in Mopani Mine, Konkola Mine and Kabwe Mine sites, and analyses of elution and content are implemented. Chemical analysis result are shown in Table 4.20.

(1) Result of Elution Test Analysis

The elution content are important data which is able to determine the actual content of health hazard heavy metals and to consider the potential of pollution. There are not established standards for the elution content in respect of hazard heavy metals in Zambia. For this reason, Japanese standards for the elution content were used for an evaluation in this study. The standard value are shown in bellow;

Standards value for elution : Refer in Japan

Component	Pb	As	Cd	Cr	Cu	Zn	Hg
Standards Value (mg/L)	0.01	0.01	0.01	0.05	-	-	0.0005

a. Mopani Mine Site

Potential of soil pollution based on the elution analysis in the Mopani mine site is shown in Figure 4.6(1).

Components more than reference value consist of Pb, Cd and Cr.

Elution contents of Pb are ranged in 0.1 to 1.8mg/L. Pollution area are distributed widely in around the mine which the content shows ten times of the reference value. Additionally, Pb content in the soil at M-S10, where locates in mine site, has 180 times of standard value.

Elution contents of Cd are ranged in 0.1 mg/L, where the contents are over the reference value at two places.

Elution contents of Cr are ranged in 0.1 to 0.8mg/L. The sites are distributed around the concentrator.

b. Konkola Mine Site

Potential of soil pollution based on the elution analysis in the Konkola mine site is shown in Figure 4.6(2).

Component more than reference value is only Pb.

Elution contents of Pb are ranged in 0.1 to 0.7 mg/L. Pollution area are limited in the mine area, which the content shows less than ten times of the reference value.

c. Kabwe Mine Site

Potential of soil pollution based on the elution analysis in the Kabwe mine site is shown in Figure 4.6 (3).

Components more than reference value consist of Pb and Cd.

Elution contents of Pb are ranged in 0.1 to 21.5 mg/L. Pollution area are distributed widely in investigation area which the contents show ten times of the reference value. In the B-S6 located in the Cu concentrate plant, the Pb has high concentration which reaches 215 times of the reference value.

Elution contents of Cd are ranged in 0.1 to 8.8 mg/L, where the contents are over the reference value at four places. However, distribution of the places are limited in around former mine site.

(2) Result of Content Analysis of Soil

There are not established standards for the content in relating of hazard heavy metals in Zambia. For this reason, Japanese standards for the content were used for an evaluation in this study. The standard value are shown in bellow;

Standards value for content : Refer in Japan

Component	Pb	As	Cd	Cr	Cu*	Zn	Hg
Standards value (mg/kg)	150	150	150	250	(125)	(120)	15

* Cu, Zn : Content Standard for Agricultural land

a. Mopani Mine Site

Potential of soil pollution based on the elution analysis in the Mopani mine site is shown in Figure 4.7(1).

Mopani mine site has extremely-high Cu content compared to the reference value, which the Zn and Cr contents show also relatively high as well.

Cu contents in the study area are ranged in 120 to 5,300 mg/kg, where the area distributes widely around the mine site. Especially, high Cu content sites locate near the concentrator plant, slag dump and waste dump. On the other hand, the content at upper stream of Kafue River shows 120 mg/kg as relatively low value. In spite of this, the Cu contents at around mine site and downstream side show 310 to 1,200 mg/kg. These phenomena mean that the Cu might be diffused far and wide around mine site.

Zn and Cr contents show relatively high and over the reference value at around concentrator and at south of slag dump.

(Correlation between components)
Correlation between components at Mopani mine site is shown in Table 4.16.

A set of correlation with Pb-Zn-Cd can be observed in the calculated values, which were calculated in 6 components among Pb, Zn, As, Cd, Cr and Cu.

Table 4.16 Correlation in Elution Components at Mopani Mine Site

	Pb	Zn	As	Cd	Cr	Cu
Pb	1.000	-	-	-	-	-
Zn	0.645	1.000	-	-	-	-
As	0.281	0.484	1.000	-	-	-
Cd	0.609	0.496	0.000	1.000	-	-
Cr	0.216	0.229	0.281	-0.055	1.000	-
Cu	0.498	0.222	0.111	0.461	-0.021	1.000

* Component: the calculation was excepted under the determination limit.

b. Konkola Mine Site

Potential of soil pollution based on the elution analysis in the Konkola mine site is shown in Figure 4.7(2).

Mopani mine site has extremely-high Cu content compared to the reference value, which Cr content shows also relatively high as well.

Cu contents in the study area are ranged in 440 to 9,900 mg/kg, where the area distributes in the mine site. Especially, high Cu content sites locate near the concentrator plant and slag dump.

Cr contents in the study area are ranged in 75 to 820 mg/kg. Cr contents of over the reference value distribute in slag dump and along Kafue River. On the other hand, The contents of less than reference value locate in mine site.

(Correlation between components)
Correlation between components of Konkola Mine is shown in Table 4.17.

Three sets of correlation with As-Cu, Pb-Zn-Cd and Zn-Cr can be observed in the calculated values, which were calculated in 6 components among Pb, Zn, As, Cd, Cr and Cu.

Table 4.17 Correlation in Elution Components at Konkola Mine Site

	Pb	Zn	As	Cd	Cr	Cu
Pb	1.000	-	-	-	-	-
Zn	0.747	1.000	-	-	-	-
As	0.623	-0.008	1.000	-	-	-
Cd	0.919	0.804	0.470	1.000	-	-
Cr	0.480	0.870	-0.379	0.507	1.000	-
Cu	0.833	0.299	0.928	0.633	-0.031	1.000

* Component: the calculation was excepted under the determination limit.

c. Kabwe Mine Site

Potential of soil pollution based on the elution analysis in the Kabwe mine site is shown in Figure 4.7(3).

Kabwe mine site has extremely-high Pb, Zn and Cu contents compared to the reference value, which the As and Cr contents show also relatively high as well.

Pb contents in the study area are ranged in 92 to 82,000 mg/kg, where the area distributes in the mine site and the peripheral area. Especially, extremely-high Pb content showing over 10,000 mg/kg sites locate in Slag dump. Additionally, the content at upper stream of the mine site has 350 mg/kg and downstream sides of southern part of the mine site (B-S5 and B-S11) show to range in 3,100 to 7,700 mg/kg as high values. These phenomena mean that the Pb might be diffused far and wide around mine site, which the contents have became high.

As contents in the study area are ranged in 13 to 460 mg/kg, where the area distributes at around slag dump in the mine site.

Cr contents are ranged in 40 to 400 mg/kg, which the contents in part of the site have relatively high and over the reference value. These area distribute in around the mine site. This phenomena are seemed like that these components on the ground have basically high background content.

(Correlation between components)
Correlation between components at Kabwe mine site is shown in Table 4.18.

Two sets of correlation with Zn-Cu and Pb-As-Cd can be observed in the calculated values, which were calculated in 6 components among Pb, Zn, As, Cd, Cr and Cu. Components of the correlation sets are similar to mineral assemblages of the mineral occurrences in the mine.

Table 4.18 Correlation in Elution Components at Kabwe Mine Site

	Pb	Zn	As	Cd	Cr	Cu
Pb	1.000	-	-	-	-	-
Zn	0.534	1.000	-	-	-	-
As	0.937	0.536	1.000	-	-	-
Cd	0.859	0.480	0.922	1.000	-	-
Cr	-0.116	0.086	-0.212	-0.183	1.000	-
Cu	0.378	0.947	0.344	0.300	0.097	1.000

* Component: the calculation was excepted under the determination limit.

(4) Summary

Following phenomena are recognized as characteristics of pollution by reference to the standard value of content in Japan.

(Mopani Mine Site)
- Are of relatively high concentration of Cu distributes in mine site and the around area.
- Ares of relatively high concentration of Zn and Cr distribute in the mine site to a limited extent.

(Konkola Mine Site)
- Are of relatively high concentration of Cu distributes widely in around mine site.
- Are of relatively high concentration of F distributes in the waste dump to a limited extent.

(Kabwe Mine Site)
- Are of relatively high concentration of Pb distributes in mine site and the around area. Additionally, the Pb is flowed out and spread in to upstream and downstream widely around mine site.
- Are of relatively high concentration of Cu distributes in the mine site.
- Are of relatively high concentration of As distributes in slag dump of the former mine site.
- Are of relatively high concentration of Cr distributes in around the mine site.

(Area of extent of pollution)

Area of extent of toxic metal content are shown in Table 4.19. Pollution area of Cu has 37.5 km^2 and the Cu is flowed out and spread in widely around the mine site. On the other hand, the same phenomena of Cu concentration are locally in Konkola mine site. The concentration of Cu in Kabwe mine site are also locally in around concentrate plant. However, the area of pollution of Pb-Zn widely spread in 59.6 km^2 in which area of the high concentration reaches to 6.2km^2.

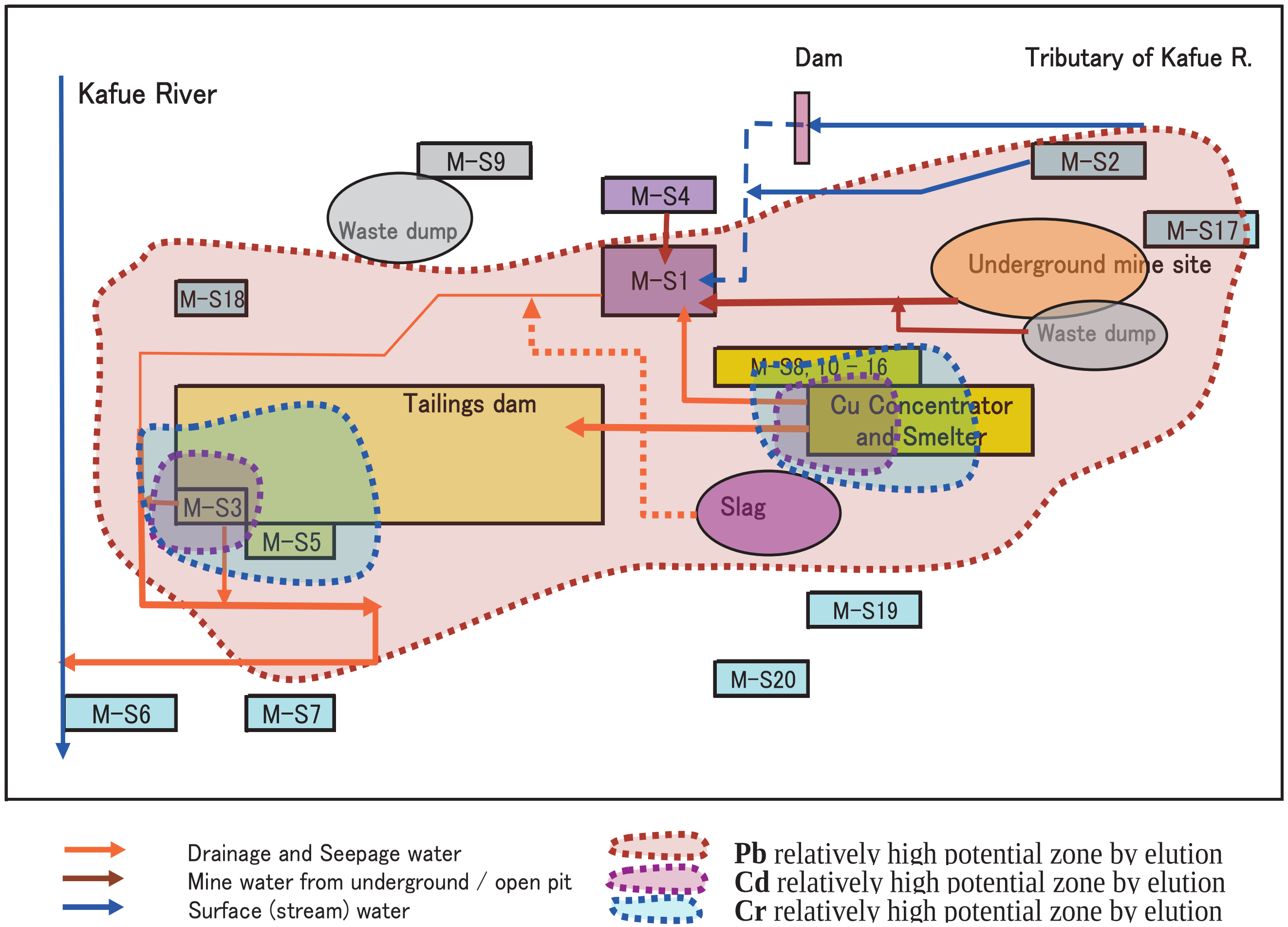
表 4.19 Area of Extent of Water Pollution in Each Mine Site

Site	Type	Area (km2)
Mufulira	Cu	37.5
Konkola	Cu	5.8
	Cu	4.6
Kabwe	Pb-Zn	59.6
	Pb-Zn High	6.2
	Cu	1.1

Table 4.20 Results of Physical Test of the Soil Sampled in the Mine Sites

Sample	Loction	Wet Density*1	Moisture	Dry Specific Gravity	True Specific Gravity	Elution Analysis						Content Analysis						Remarks
						Pb	Zn	As	Cd	Cr	Cu	Pb	Zn	As	Cd	Cr	Cu	
No.		g/cm^3	%			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
M-S1	Mopani	1.56	13.8	1.35	2.58	0.7	0.2	<0.1	<0.1	<0.1	8.5	23	30	16	0.5	470	2300	light brown soil
M-S2	Mopani	2.03	13.1	1.76	2.59	0.6	0.2	<0.1	<0.1	<0.1	0.6	16	40	20	0.9	94	120	light brown soil
M-S3	Mopani	1.73	18.9	1.41	2.71	1.3	0.2	<0.1	0.1	0.4	0.8	15	24	25	1.2	26	2100	white fine sand at tailings
M-S4	Mopani	1.68	18.8	1.36	2.57	<0.1	0.1	<0.1	<0.1	<0.1	10.9	19	39	12	1.3	27	3700	brown soil
M-S5	Mopani	2.31	13.1	2.01	2.62	0.2	0.1	<0.1	<0.1	0.5	5.5	55	160	17	2.1	580	3300	brown soil
M-S6	Mopani	2.00	15.4	1.69	2.7	0.1	<0.1	<0.1	<0.1	0.4	0.6	13	21	3.3	1.7	59	310	brown soil
M-S7	Mopani	1.29	32.4	0.87	2.56	<0.1	0.1	<0.1	<0.1	0.7	1.8	30	51	8.1	2.5	120	1300	brown soil
M-S8	Mopani	2.33	1.5	2.29	3.78	<0.1	<0.1	<0.1	<0.1	0.8	2.5	90	610	24	4.7	150	3900	black slag at slag dump
M-S9	Mopani	1.39	6.8	1.29	2.66	<0.1	<0.1	<0.1	<0.1	0.5	2.9	33	37	15	2.4	30	4300	light brown soil at waste rock dump
M-S10	Mopani	2.18	17.6	1.80	2.72	1.8	0.1	<0.1	0.1	1.7	8.4	48	170	11	3.0	300	4900	light brown soil include green Cu stain
M-S11	Mopani	2.30	13.4	1.99	2.64	0.5	<0.1	<0.1	<0.1	0.2	3.1	25	33	6.1	3.1	27	5300	light brown soil beside at slag dump
M-S12	Mopani	1.93	12.7	1.68	2.70	0.6	<0.1	<0.1	<0.1	0.1	4.1	42	35	13	2.8	47	5100	light brown soil near slag dump
M-S13	Mopani	1.65	14.0	1.42	2.61	0.4	0.8	<0.1	<0.1	<0.1	84.4	96	45	8.1	3.8	79	5200	brown soil
M-S14	Mopani	1.96	13.2	1.70	2.64	0.3	0.8	<0.1	<0.1	<0.1	71.9	16	39	10	3.4	51	5100	brown soil
M-S15	Mopani	2.47	13.5	2.14	2.64	0.4	0.2	<0.1	<0.1	<0.1	3.0	43	67	5.5	4.2	71	1200	brown soil
M-S16	Mopani	1.89	6.7	1.76	2.68	0.5	0.2	<0.1	<0.1	<0.1	14.2	15	51	4.9	2.5	44	4200	light brown soil
M-S17	Mopani	1.75	12.9	1.52	2.78	0.8	0.2	<0.1	<0.1	<0.1	2.4	6.7	35	10	3.7	230	300	light brown soil
M-S18	Mopani	1.74	17.0	1.44	2.62	0.3	0.1	<0.1	<0.1	<0.1	5.3	3.7	22	5.3	0.6	94	1200	light brown soil
M-S19	Mopani	2.02	16.7	1.68	2.48	0.3	0.1	<0.1	<0.1	<0.1	3.6	15	22	5.5	0.8	43	810	brown soil
M-S20	Mopani	1.64	15.6	1.39	2.55	<0.1	0.3	<0.1	<0.1	<0.1	3.9	22	34	6.8	0.7	58	1000	light brown soil
K-S1	Konkola	2.16	15.7	1.82	2.90	0.1	<0.1	<0.1	<0.1	<0.1	0.8	42	97	1.7	1.7	820	4200	gray soil at tailings
K-S2	Konkola	2.16	11.2	1.92	2.66	0.3	0.9	<0.1	<0.1	<0.1	3.5	15	16	1.9	1.0	92	440	brown soil
K-S3	Konkola	1.73	24.9	1.30	2.44	<0.1	0.3	<0.1	<0.1	<0.1	3.4	21	61	0.3	1.3	260	690	light brown soil
K-S4	Konkola	1.64	14.7	1.40	2.62	0.7	0.1	<0.1	<0.1	<0.1	21.3	15	17	5.0	0.6	55	2900	brown soil
K-S5	Konkola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	gray soil besite at outcrop
K-S6	Konkola	1.95	9.8	1.75	-	<0.1	0.2	<0.1	<0.1	<0.1	19.6	46	54	24	1.8	75	9900	light brown soil at waste dump
B-S1	Kabwe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	brown soil
B-S2	Kabwe	1.85	17.6	1.52	2.54	2.4	14.6	<0.1	<0.1	<0.1	0.9	34000	10000	27	7.7	200	1100	gray soil beside at past slag dunp
B-S3	Kabwe	2.61	9.0	2.37	2.90	0.4	1.1	<0.1	<0.1	<0.1	<0.1	29000	55000	72	16	400	2200	coarse sand beside at past slag dunp
B-S4	Kabwe	1.28	42.0	0.74	3.07	5.8	647.5	<0.1	1.8	<0.1	<0.1	82000	53000	460	140	140	1600	brown soil at near circulation pond
B-S5	Kabwe	1.66	19.9	1.33	2.64	0.5	2.6	<0.1	<0.1	<0.1	<0.1	3100	3700	27	8.3	290	170	brown soil
B-S6	Kabwe	1.63	19.2	1.32	2.52	21.5	71.1	<0.1	0.1	<0.1	2.6	12000	22000	31	33	170	1000	brown soil
B-S7	Kabwe	2.30	11.0	2.05	3.02	1.5	4.5	<0.1	<0.1	<0.1	<0.1	20000	22000	110	68	230	1500	brown soil in past tailings
B-S8	Kabwe	1.59	38.1	0.98	3.22	15.3	351.3	<0.1	8.8	<0.1	<0.1	73000	39000	360	91	150	1500	brown soil in past tailings
B-S9	Kabwe	2.33	2.9	2.26	3.52	0.6	5.9	<0.1	<0.1	<0.1	<0.1	9500	81000	79	17	190	4100	coarse gray sand in past slag dunp
B-S10	Kabwe	1.69	12.1	1.48	2.62	8.3	10.1	<0.1	<0.1	<0.1	0.4	5100	4700	25	8.3	340	510	brown soil
B-S11	Kabwe	1.38	21.1	1.09	2.52	11.3	30.6	<0.1	<0.1	<0.1	0.2	7700	11000	42	32	320	280	brown soil
B-S12	Kabwe	1.62	18.0	1.33	2.51	3.1	10.2	<0.1	<0.1	<0.1	<0.1	410	1500	13	3.2	320	90	brown soil
B-S13	Kabwe	1.77	17.7	1.46	2.51	6.8	9.6	<0.1	<0.1	<0.1	0.1	1000	1200	15	4.5	98	150	brown soil
B-S14	Kabwe	1.76	16.5	1.47	2.49	3.0	7.8	<0.1	<0.1	<0.1	<0.1	350	980	16	3.1	110	78	brown soil
B-S15	Kabwe	2.06	17.8	1.69	2.72	16.6	40.0	<0.1	0.1	<0.1	0.9	19000	24000	86	63	160	890	dark brown soil
B-S16	Kabwe	2.12	16.9	1.76	2.59	3.7	11.8	<0.1	<0.1	<0.1	1.6	3200	12000	32	4.2	190	560	brown soil
B-S17	Kabwe	1.65	18.8	1.34	2.56	0.1	1.0	<0.1	<0.1	<0.1	<0.1	92	84	26	1.0	40	65	dark brown soil

*1: Wet Specific Density is almost same as apparent specific gravity.



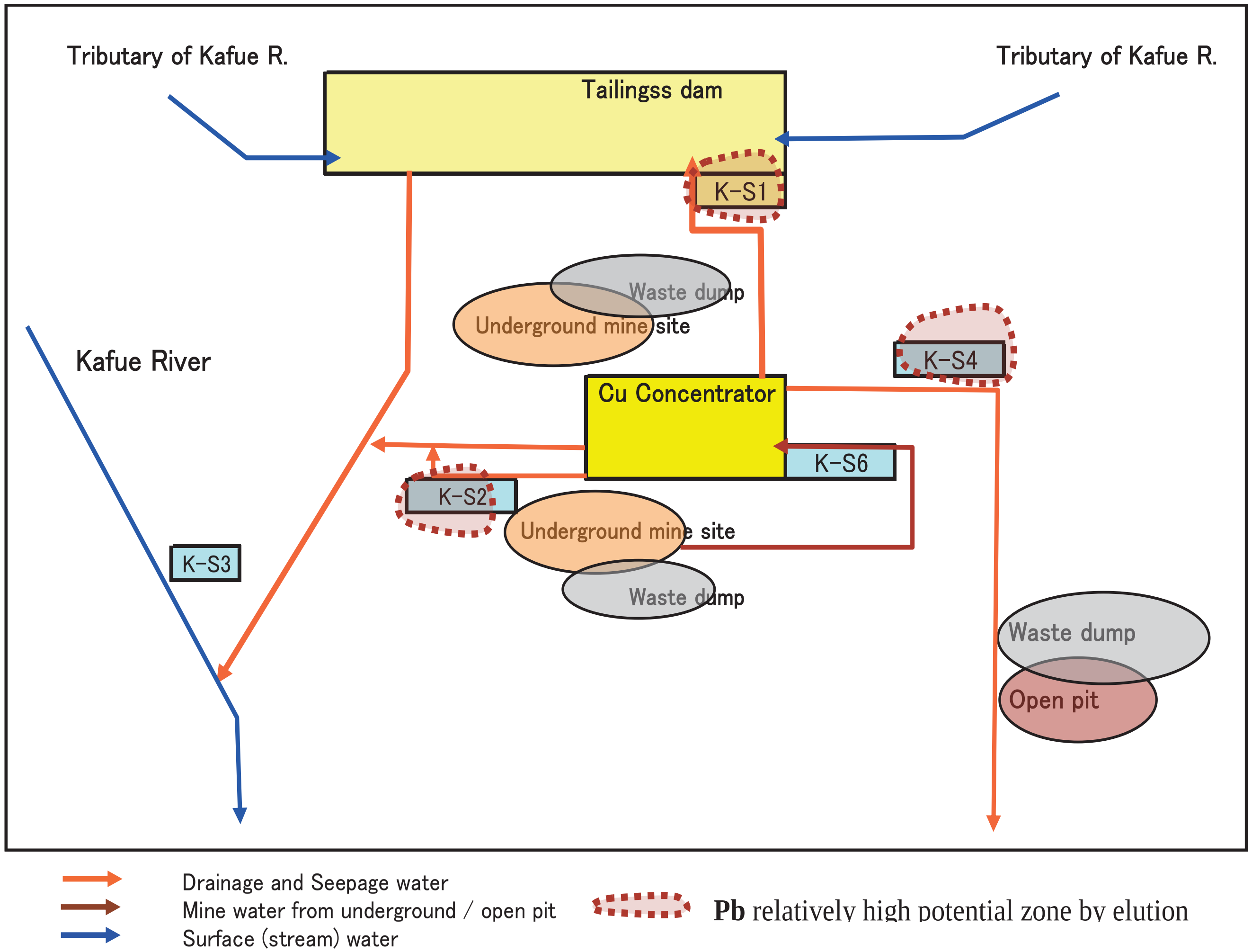
(mg/L)

No.	Pb	Zn	As	Cd	Cr	Cu
M-S1	0.7	0.2	<0.1	<0.1	<0.1	8.5
M-S2	0.6	0.2	<0.1	<0.1	<0.1	0.6
M-S3	1.3	0.2	<0.1	0.1	0.4	0.8
M-S4	<0.1	0.1	<0.1	<0.1	<0.1	10.9
M-S5	0.2	0.1	<0.1	<0.1	0.5	5.5
M-S6	0.1	<0.1	<0.1	<0.1	0.4	0.6
M-S7	<0.1	0.1	<0.1	<0.1	0.7	1.8
M-S8	<0.1	<0.1	<0.1	<0.1	0.8	2.5
M-S9	<0.1	<0.1	<0.1	<0.1	0.5	2.9
M-S10	1.8	0.1	<0.1	0.1	1.7	8.4
M-S11	0.5	<0.1	<0.1	<0.1	0.2	3.1
M-S12	0.6	<0.1	<0.1	<0.1	0.1	4.1
M-S13	0.4	0.8	<0.1	<0.1	<0.1	84.4
M-S14	0.3	0.8	<0.1	<0.1	<0.1	71.9
M-S15	0.4	0.2	<0.1	<0.1	<0.1	3.0
M-S16	0.5	0.2	<0.1	<0.1	<0.1	14.2
M-S17	0.8	0.2	<0.1	<0.1	<0.1	2.4
M-S18	0.3	0.1	<0.1	<0.1	<0.1	5.3
M-S19	0.3	0.1	<0.1	<0.1	<0.1	3.6
M-S20	<0.1	0.3	<0.1	<0.1	<0.1	3.9
ES (Japan)	0.01	-	0.01	0.01	0.05	-

ES: Environmental Standard for Soil (Elution Test)

Very high concentration (>=(ES-1)*100
High (>=(ES-1)*10, <(ES-1)*100)
Moderate (>ES-1, < (ES-1)*10)
Low <ES

Figure 4.9 (1) Soil Environmental Condition based on the Elution Test Analysis in the Mopani Mine Site



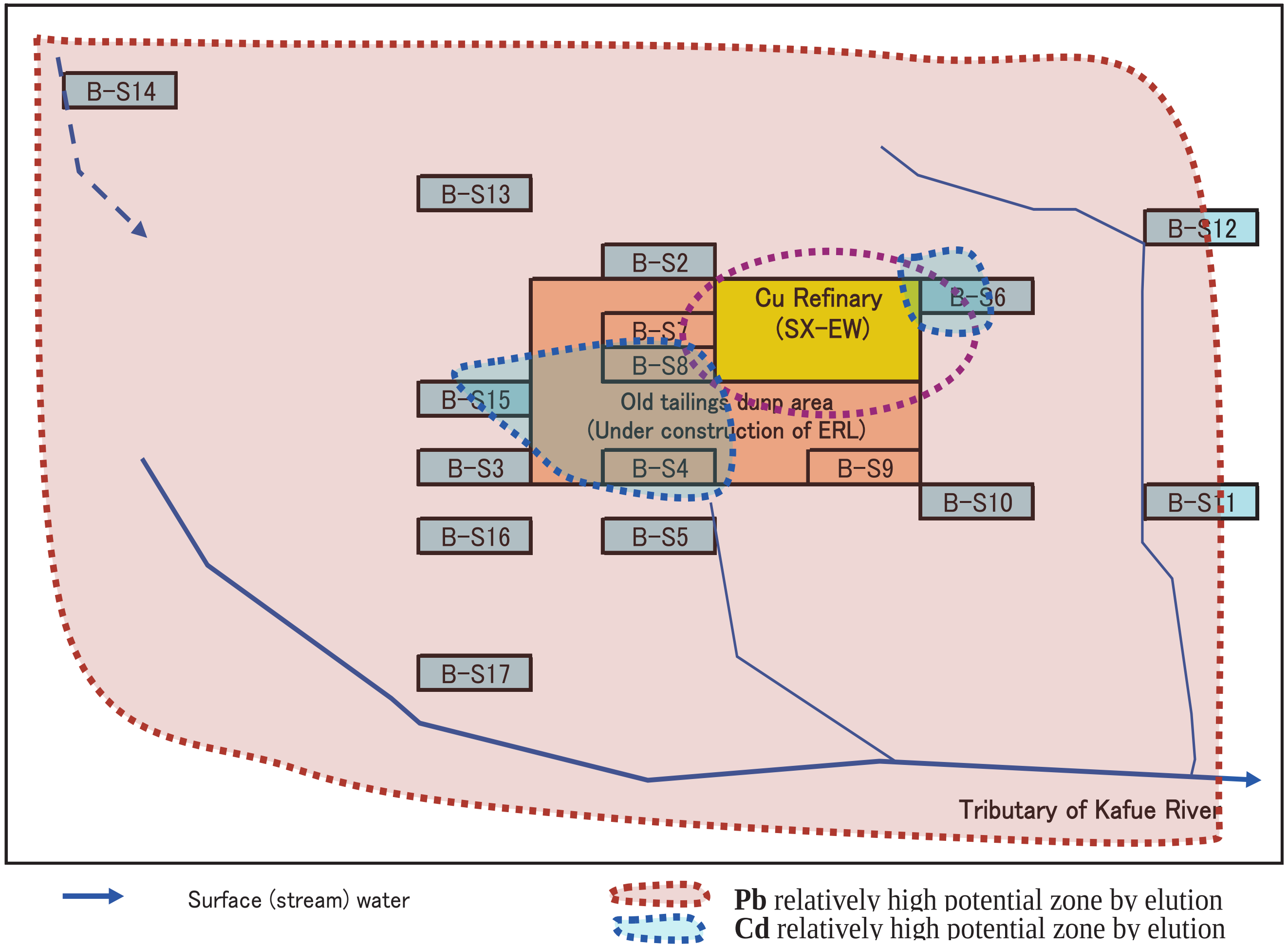
(mg/L)

No.	Pb	Zn	As	Cd	Cr	Cu
K-S1	0.1	<0.1	<0.1	<0.1	<0.1	0.8
K-S2	0.3	0.9	<0.1	<0.1	<0.1	3.5
K-S3	<0.1	0.3	<0.1	<0.1	<0.1	3.4
K-S4	0.7	0.1	<0.1	<0.1	<0.1	21.3
K-S6	<0.1	0.2	<0.1	<0.1	<0.1	19.6
ES (Japan)	0.01	−	0.01	0.01	0.05	−

ES: Environmental Standard for Soil (Elution Test)

Very high concentration (>=(ES−1)*100
High (>=(ES−1)*10, <(ES−1)*100)
Moderate (>ES−1, < (ES−1)*10)
Low <ES

Figure 4.9 (2) Soil Environmental Condition based on the Elution Test Analysis in the Konkola Mine Site



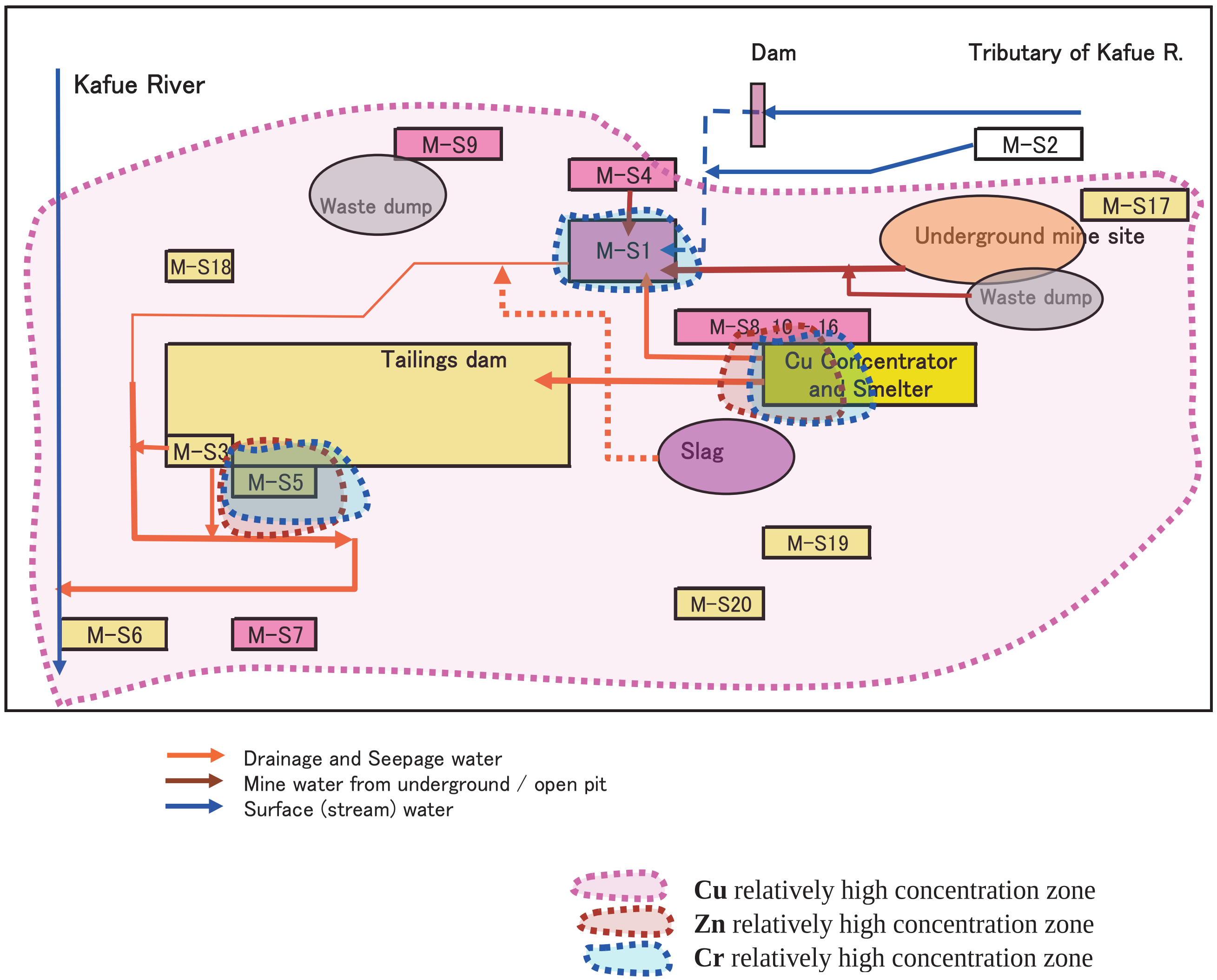
(mg/L)

No.	Pb	Zn	As	Cd	Cr	Cu
B-S2	2.4	14.6	<0.1	<0.1	<0.1	0.9
B-S3	0.4	1.1	<0.1	<0.1	<0.1	<0.1
B-S4	5.8	647.5	<0.1	1.8	<0.1	<0.1
B-S5	0.5	2.6	<0.1	<0.1	<0.1	<0.1
B-S6	21.5	71.1	<0.1	0.1	<0.1	2.6
B-S7	1.5	4.5	<0.1	<0.1	<0.1	<0.1
B-S8	15.3	351.3	<0.1	8.8	<0.1	<0.1
B-S9	0.6	5.9	<0.1	<0.1	<0.1	<0.1
B-S10	8.3	10.1	<0.1	<0.1	<0.1	0.4
B-S11	11.3	30.6	<0.1	<0.1	<0.1	0.2
B-S12	3.1	10.2	<0.1	<0.1	<0.1	<0.1
B-S13	6.8	9.6	<0.1	<0.1	<0.1	0.1
B-S14	3.0	7.8	<0.1	<0.1	<0.1	<0.1
B-S15	16.6	40.0	<0.1	0.1	<0.1	0.9
B-S16	3.7	11.8	<0.1	<0.1	<0.1	1.6
B-S17	0.1	1.0	<0.1	<0.1	<0.1	<0.1
ES (Japan)	0.01	–	0.01	0.01	0.05	–

ES: Environmental Standard for Soil (Elution Test)

- Very high concentration (>=(ES-1)*100
- High (>=(ES-1)*10, <(ES-1)*100)
- Moderate (>ES-1, < (ES-1)*10)
- Low <ES

Figure 4.9 (3)　Soil Environmental Condition based on the Elution Test Analysis in the Kabwe Mine Site



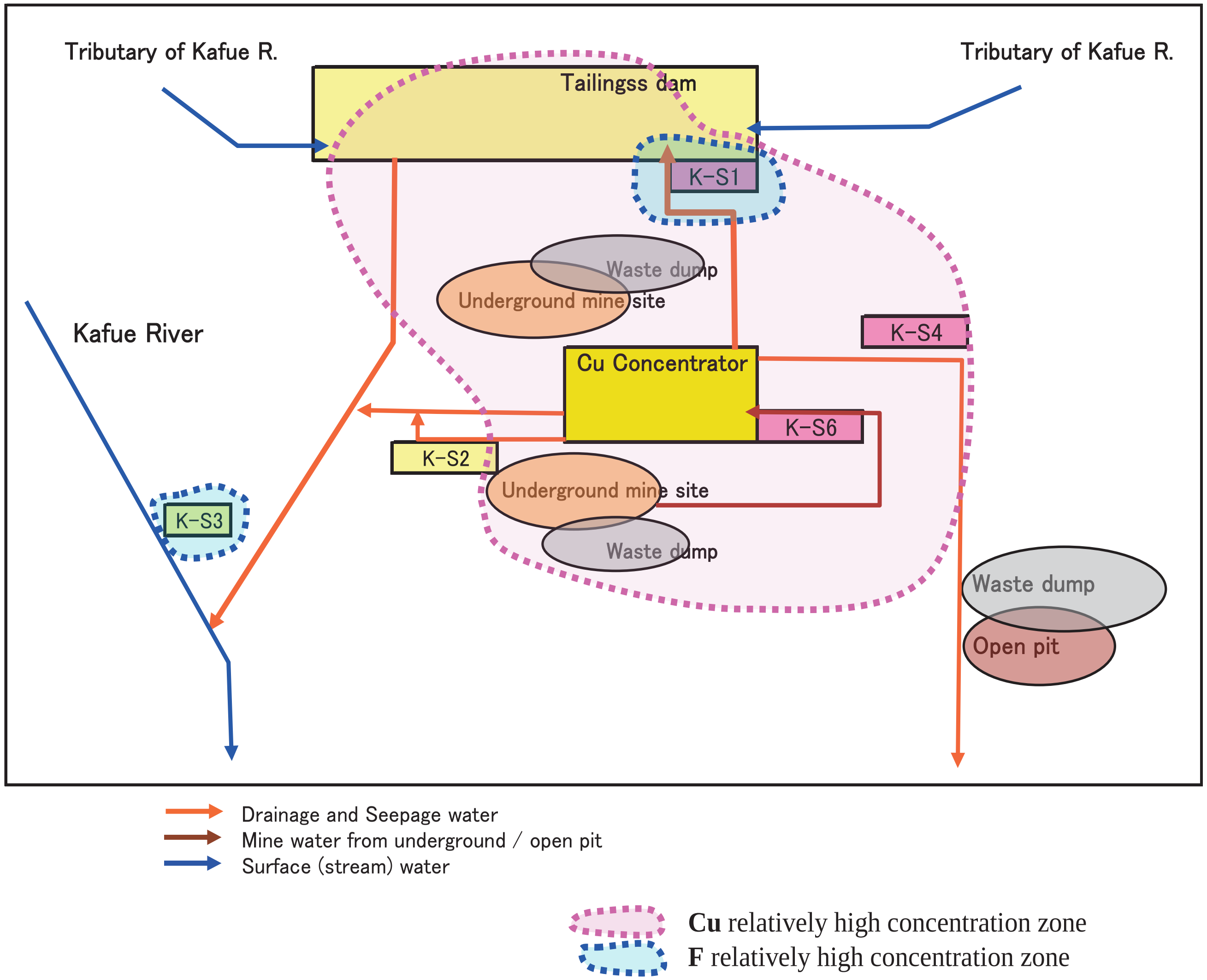
(mg/kg)

No.	Pb	Zn	As	Cd	Cr	Cu
M-S1	23	30	16	0.5	470	2300
M-S2	16	40	20	0.9	94	120
M-S3	15	24	25	1.2	26	2100
M-S4	19	39	12	1.3	27	3700
M-S5	55	160	17	2.1	580	3300
M-S6	13	21	3.3	1.7	59	310
M-S7	30	51	8.1	2.5	120	1300
M-S8	90	610	24	4.7	150	3900
M-S9	33	37	15	2.4	30	4300
M-S10	48	170	11	3.0	300	4900
M-S11	25	33	6.1	3.1	27	5300
M-S12	42	35	13	2.8	47	5100
M-S13	96	45	8.1	3.8	79	5200
M-S14	16	39	10	3.4	51	5100
M-S15	43	67	5.5	4.2	71	1200
M-S16	15	51	4.9	2.5	44	4200
M-S17	6.7	35	10	3.7	230	300
M-S18	3.7	22	5.3	0.6	94	1200
M-S19	15	22	5.5	0.8	43	810
M-S20	22	34	6.8	0.7	58	1000
ES (Japan)	150	(150)	150	150	250	125

ES: Environmental Standard for Soil (Metal Content)

- Very high concentration (>=(ES−1)*100
- High (>=(ES−1)*10, <(ES−1)*100)
- Moderate (>ES−1, < (ES−1)*10)
- Low <ES

Figure 4.10 (1) Soil Environmental Condition based on the Metal Content Analysis in the Mopani Mine Site



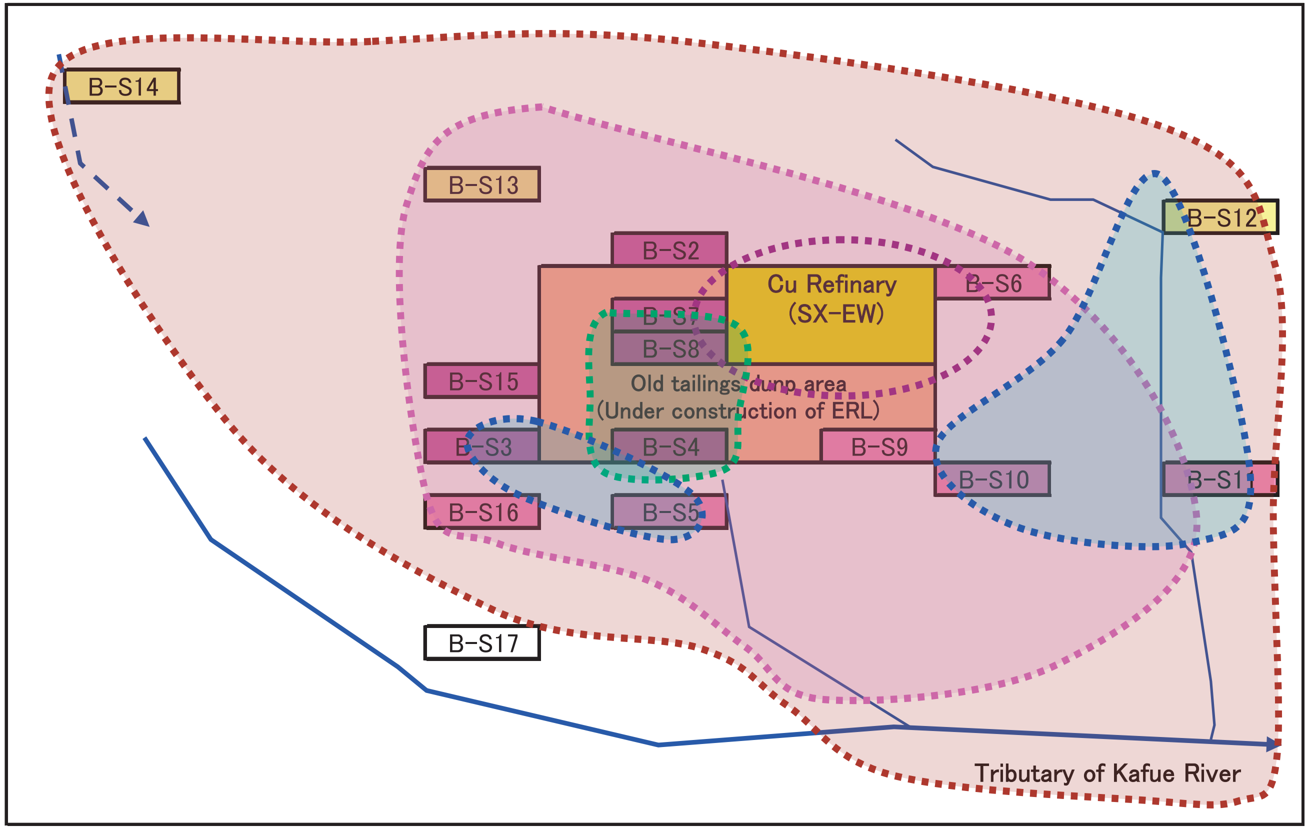
(mg/kg)

No.	Pb	Zn	As	Cd	Cr	Cu
K-S1	42	97	1.7	1.7	820	4200
K-S2	15	16	1.9	1.0	92	440
K-S3	21	61	0.3	1.3	260	690
K-S4	15	17	5.0	0.6	55	2900
K-S6	46	54	24	1.8	75	9900
ES (Japan)	150	(150)	150	150	250	125

ES: Environmental Standard for Soil (Metal Content)

- Very high concentration (>=(ES-1)*100
- High (>=(ES-1)*10, <(ES-1)*100)
- Moderate (>ES-1, < (ES-1)*10)
- Low <ES

Figure 4.10 (2) Soil Environmental Condition based on the Metal Content Analysis in the Konkola Mine Site



Surface (stream) water

(mg/kg)

No.	Pb	Zn	As	Cd	Cr	Cu
B-S2	34000	10000	27	7.7	200	1100
B-S3	29000	55000	72	16	400	2200
B-S4	82000	53000	460	140	140	1600
B-S5	3100	3700	27	8.3	290	170
B-S6	12000	22000	31	33	170	1000
B-S7	20000	22000	110	68	230	1500
B-S8	73000	39000	360	91	150	1500
B-S9	9500	81000	79	17	190	4100
B-S10	5100	4700	25	8.3	340	510
B-S11	7700	11000	42	32	320	280
B-S12	410	1500	13	3.2	320	90
B-S13	1000	1200	15	4.5	98	150
B-S14	350	980	16	3.1	110	78
B-S15	19000	24000	86	63	160	890
B-S16	3200	12000	32	4.2	190	560
B-S17	92	84	26	1.0	40	65
ES (Japan)	150	(150)	150	150	250	125

ES: Environmental Standard for Soil (Metal Content)

- Very high concentration (>=(ES−1)*100
- High (>=(ES−1)*10, <(ES−1)*100)
- Moderate (>ES−1, < (ES−1)*10)
- Low <ES

Pb and Zn relatively high concentration zone
Cu relatively high concentration zone
As relatively high concentration zone
Cr relatively high concentration zone

Figure 4.10 (3) Soil Environmental Condition based on the Metal Content Analysis in the Kabwe Mine Site

4.4.9 Outline of Mine Pollution Control

Outline of mine pollution control including water and soil in the Mufulina, Konkola and Kabwe mine sites is shown as below.

(1) Water Contamination Measures

As results of evaluation using the Zambian Effluent Standard, water contamination due to F and SO_4^{-2} in the Mufulina mine site was confirmed, however the water contamination in the Konkola and Kabwe mine sites was not found so far.

In the case of evaluation using Japanese Environmental Standard as reference, water contamination by Cd, Pb and Zn in the Kabwe mine site was definitely recognized.

a. Outline of Water Contamination Measures in the Mufulina Mine Site

The water contamination in the Mufulina mine site is limited only discharged and seeped water from the tailings dam. Therefore, it is necessary to carry out countermeasures in case of beyond the Effluent Standard through the year by periodical monitoring at two points.

Hereafter, Research of source of F and countermeasures based on the research should be examined. However, in case that F is containing in the tailings, the water treatment for F is required.

b. Outline of Water Contamination Measures in the Kabwe Mine Site

Around the present Cu Smelter site, B-W19 of drainage water, three points, including B-W10 and B-W12 of groundwater as monitoring of water, shows Pb, Cd and Zn to be exceeded the reference standard. These contamination is thought to be occurred from the old Pb-Zn mine. Therefore, it is thought local (small scaled) measures is not useful.

It is necessary to control the outflow of contaminated surface water and to prevent the contaminated water to infiltrate into the underground.

-Spillage prevention measures: Drainage water courses from the mine site are improved to trihedral concrete water courses for prevention of spillage and infiltration contaminated water into underground. And, it is necessary to install settlement ponds at the appropriate locations for prevention of the contaminated soil, which is eluted harmful metals, and to sediment the contaminated soil at the ponds. The locations of settlement ponds are recommended to be between B-W13 and B-W16 and downstream of B-W19.

-Infiltration prevention measures: As the source of water contamination is thought to be old Pb-Zn mine site, it is necessary to improve the site of old tailings dam, including smoothing surface of tailings, soil covering and vegetation, for the protection of soil erosion and infiltration of rainwater.

(2) Soil Contamination Measures

As results of evaluation using the Japanese Environmental Standard as reference, the following soil contaminations are recognized.

- -Mufulina mine site: The Cu content in the soil shows relatively high concentration and widespread in and outside of the mine site. Although the contents of Zn and Cr in the soil show also relatively high concentration, the area of relatively high concentration is restrictively distributed.
- -Konkola mine site: The Cu content in the soil shows relatively high concentration and is widely distributed in the mine site. Although the content of F in the soil shows also relatively high concentration, the F content is restrictively distributed in the tailings dam.
- -Kabwe mine site: The Pb content in the soil shows relatively high concentration and widespread in and around the mine site. The contents of Cu, As and Cr in the soil show also relatively high concentration, but these metals of relatively high concentration is restrictively distributed in the mine site.

a. Outline of Soil Contamination Measures in the Mufulina Mine Site

Cu content of soil in the Mufulina mine site is exceeded the reference standard, and the Cu distribution is widespread not only in the mine site but also upper stream and downstream. As Japanese reference standard of Cu is for agricultural standard, it is necessary to research and examine the influence of crops.

b. Outline of Soil Contamination Measures in the Konkola Mine Site

Cu content of soil in the Mufulina mine site is exceeded the reference standard, and the Cu distribution is distributed in the mine site. As Japanese reference standard of Cu is for agricultural standard, it is necessary to research and examine the influence of crops.

c. Outline of Soil Contamination Measures in the Kabwe Mine Site

In the Kabwe mine site, soil contaminated area due to Pb and Zn is inferred to be very wide as 59.6 km^2, particularly the area of higher concentration zone is 6.2 km^2, showing to be widespread in and outside of the old mine site. The soil contaminated zone of Cu is restrictively distributed in the Cu Smelter site.

Although the countermeasures of Pb and Zn spreading widely are thought to be very difficult, it is basically necessary to carry out same measures as water contamination measures.

- -Spillage prevention measures: Drainage water courses from the mine site are improved to trihedral concrete water courses for prevention of spillage and infiltration contaminated water into underground. And, it is necessary to install settlement ponds at the appropriate locations for prevention of the contaminated soil, which is eluted harmful metals, and to sediment the contaminated soil at the ponds. The locations of settlement ponds are recommended to be between B-W13 and B-W16 and downstream of B-W19.

-Infiltration prevention measures: As the source of water contamination is thought to be old Pb-Zn mine site, it is necessary to improve the site of old tailings dam, including smoothing surface of tailings, soil covering and vegetation, for the protection of soil erosion and infiltration of rainwater.

-Mitigation measures of risk to local people, living in and around the mine site: Improvements of playgrounds, parks, etc., including soil covering, turf, etc., pavement of roads and others are useful for mitigation of direct exposures from the harmful metals.

CHAPTER 5 CONSIDERATION AND SUPPORT FOR THE COUNTERMEASURES OF ENVIRONMENT POLLUTION AND SAFETY

In this chapter, draft proposals for the countermeasures of environment pollution, mine safety and the direction for the support were considered in this chapter, which the consideration was based on the information about concerned site relating to mine environment and safety during this study.

5.1 Countermeasures of Environmental Pollution and Safety

5.1.1 Malawi

Countermeasure for the acid mine drainage at Mchenga coal mine and improvement for the safety at Muzimba gems mining site as improvement examples in respect of mine environment and safety were described in bellow.

(1) Consideration for the Countermeasure of Environment Pollution

Pit wastewater from the abandoned mine was observed as an existing acidic water which the water showed pH 3.01, reached over 5mg/L in the total metal content and reached over 2mg/L in the Zn content based on the simple water analysis on the site. The flow rate of the mine water showed approximately several dozens, however, the water are concerned about influences animals and vegetations around the place. For this reason, the potential of the pollution thought to be possible high emergence and the countermeasure is required for improvement of the outflow of acidic water.

a. An Example of Improvement for the Acid Water at Mchenga Coal Mine

Outline view of the abandoned pit site at the mine is shown in Figure 5.1.

The coal bed is distributed in the level of under to horizontal level of ventilation pits, which the mining pits locate mostly at under the ventilation. Based on the layout of these pits, the acid water would be occurred in existing pits, where the sulfur content in the coal layer and host rock is oxidized and sulfuric acid is generated in the process. The ground water are already reached the level of ventilation pit. This condition means the air shutout method as an oxidative protection is used for to constrain the occurrence of sulfuric acid (Figure 5.2).

Surface ground has caved in the mouth of the pit where corresponds in the site for the countermeasure of the acid mine water. The site is necessary for construction of slope protection, land grading, stabilization around pit mouth and construction of protection dike (approximately

2m high) as a countermeasure of collapse at around the mouth. An example of the countermeasure is shown in Figure 5.3.

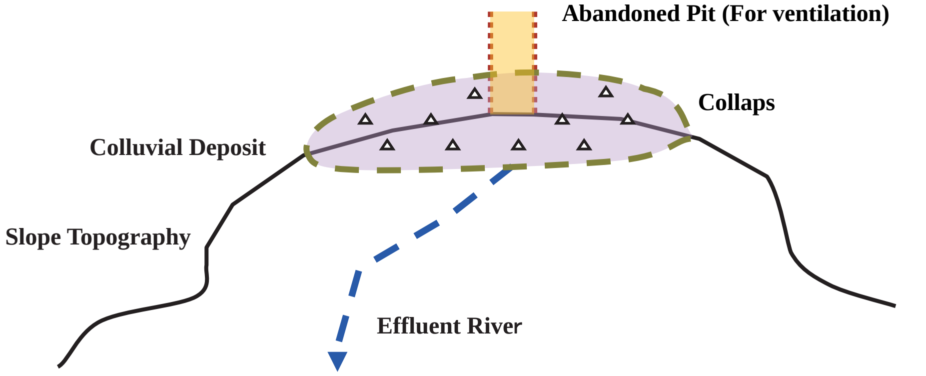


Figure 5.1 Site Situation of Abandoned Pit at Mchenga Coal Mine

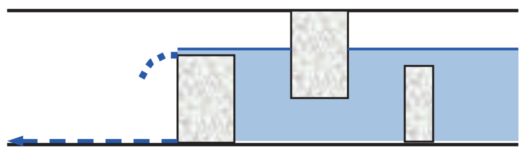


Figure 5.2 Air Protection Method at the Pit Mouth

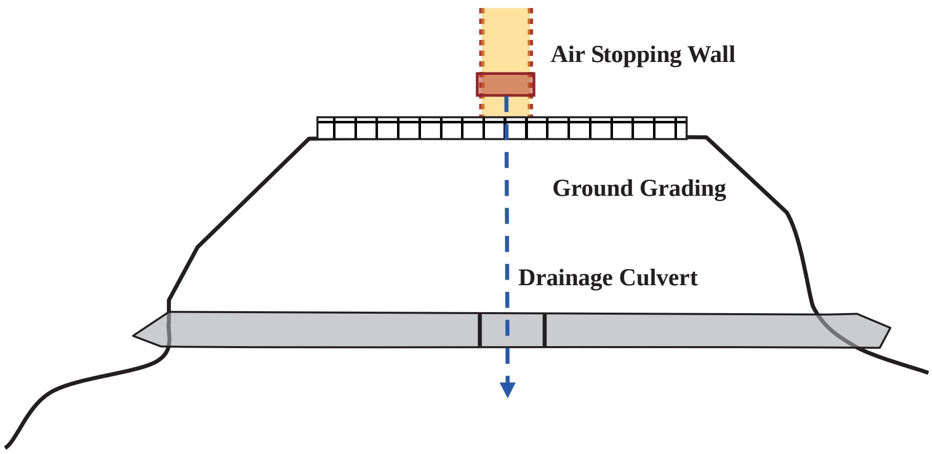


Figure 5.3 An Example of Improvement for Abandoned Pit at Mchenga Coal Mine

b. Monitoring of Drainage Water

Drainage water is necessary for to observe the quality on the routine basis by monitoring which the quality should be kept neutrality among pH6-7. Additionally, amount of the discharge will be degraded by the air sopping wall. After the degradation, the water quality will be improved as well.

(2) Consideration of Countermeasure on Mine Safety

Digging depth of the Muzimba gems mine is relatively shallow. However, the width of the digging place are narrow and the wall shows steep shape. In view of this, the site has risks of falling and over-turning, and there are a number of challenges for these kind of issues. An example of improvement for these issues at site is shown in bellow.

(Access to the Face)

There are hazards about falling and over-turning to approach the digging face. Handrest and extension rope are need to be fixed up at such places (Figure 5.4). Miner should be obligated to wear PPE such as hard hat, protection goggles and steel-toed boots, and to receive safety instruction. Based on the situation at the site, there are a lot of concerns about the safety and the sites are needed for the improvements.

Figure 5.4 Countermeasure for Safety at the Mining Site

5.1.2 Zambia

Overview of countermeasure and improvement for water and soil at Mopani Mine Site, Konkola Mine Site and Kabwe Mine Site, which were objected for the Second Site Investigation, is described as follows;

(1) Water Contamination Measures

As results of evaluation using the Zambian Effluent Standard, water contamination due to F and SO_4^{-2} in the Mopani mine site was confirmed, however the water contamination in the Konkola and Kabwe mine sites was not found so far.

In the case of evaluation using Japanese Environmental Standard as reference, water contamination by Cd, Pb and Zn in the Kabwe mine site was definitely recognized.

a. Outline of Water Contamination Measures in the Mopani Mine Site

The water contamination in the Mopani mine site is limited only discharged and seeped water from the tailings dam. Therefore, it is necessary to carry out countermeasures in case of beyond the Effluent Standard through the year by periodical monitoring at two points.

Hereafter, Research of source of F and countermeasures based on the research should be examined. However, in case that F is containing in the tailings, the water treatment for F is required.

b. Outline of Water Contamination Measures in the Kabwe Mine Site

Around the present Cu Smelter site, B-W19 of drainage water, three points, including B-W10 and B-W12 of groundwater as monitoring of water, shows Pb, Cd and Zn to be exceeded the reference standard. These contamination is thought to be occurred from the old Pb-Zn mine. Therefore, it is thought local (small scaled) measures is not useful.

It is necessary to control the outflow of contaminated surface water and to prevent the contaminated water to infiltrate into the underground.

-Spillage prevention measures: Drainage water courses from the mine site are improved to trihedral concrete water courses for prevention of spillage and infiltration contaminated water into underground. And, it is necessary to install settlement ponds at the appropriate locations for prevention of the contaminated soil, which is eluted harmful metals, and to sediment the contaminated soil at the ponds. The locations of settlement ponds are recommended to be between B-W13 and B-W16 and downstream of B-W19.

-Infiltration prevention measures: As the source of water contamination is thought to be old Pb-Zn mine site, it is necessary to improve the site of old tailings dam, including smoothing surface of tailings, soil covering and vegetation, for the protection of soil erosion and infiltration of rainwater.

(2) Soil Contamination Measures

As results of evaluation using the Japanese Environmental Standard as reference, the following soil contaminations are recognized.

-Mopani mine site: The Cu content in the soil shows relatively high concentration and widespread in and outside of the mine site. Although the contents of Zn and Cr in the soil show also relatively high concentration, the area of relatively high concentration is restrictively distributed.

-Konkola mine site: The Cu content in the soil shows relatively high concentration and is widely distributed in the mine site. Although the content of F in the soil shows also relatively high concentration, the F content is restrictively distributed in the tailings dam.

-Kabwe mine site: The Pb content in the soil shows relatively high concentration and widespread in and around the mine site. The contents of Cu, As and Cr in the soil show also relatively high concentration, but these metals of relatively high concentration is restrictively distributed in the mine site.

a. Outline of Soil Contamination Measures in the Mopani Mine Site

Cu content of soil in the Mopani mine site is exceeded the reference standard, and the Cu distribution is widespread not only in the mine site but also upper stream and downstream. As Japanese reference standard of Cu is for agricultural standard, it is necessary to research and examine the influence of crops.

b. Outline of Soil Contamination Measures in the Konkola Mine Site

Cu content of soil in the Mopani mine site is exceeded the reference standard, and the Cu distribution is distributed in the mine site. As Japanese reference standard of Cu is for agricultural standard, it is necessary to research and examine the influence of crops.

c. Outline of Soil Contamination Measures in the Kabwe Mine Site

In the Kabwe mine site, soil contaminated area due to Pb and Zn is inferred to be very wide as 59.6 km2, particularly the area of higher concentration zone is 6.2 km2, showing to be widespread in and outside of the old mine site. The soil contaminated zone of Cu is restrictively distributed in the Cu Smelter site.

Although the countermeasures of Pb and Zn spreading widely are thought to be very difficult, it is basically necessary to carry out same measures as water contamination measures.

-Spillage prevention measures: Drainage water courses from the mine site are improved to trihedral concrete water courses for prevention of spillage and infiltration contaminated water into underground. And, it is necessary to install settlement ponds at the appropriate locations for prevention of the contaminated soil, which is eluted harmful metals, and to sediment the contaminated soil at the ponds. The locations of settlement ponds are recommended to be between B-W13 and B-W16 and downstream of B-W19.

-Infiltration prevention measures: As the source of water contamination is thought to be old Pb-Zn mine site, it is necessary to improve the site of old tailings dam, including smoothing surface of tailings, soil covering and vegetation, for the protection of soil erosion and infiltration of rainwater.

-Mitigation measures of risk to local people, living in and around the mine site: Improvements of playgrounds, parks, etc., including soil covering, turf, etc., pavement of roads and others are useful for mitigation of direct exposures from the harmful metals.

5.2 Assumed Future Support

5.2.1 Support relating to Management for Mine Environment and Safety

Directions of support relating to the management for mine environment and safety in object countries are suggested as bellow.

(1) Support for Revision of Related Lows of Mine Environment and Mine Inspection

➢ Main object countries: Malawi and Madagascar

- Content of the support: Launch of internal committee in respect of the revision, participation in the committee, technical guidance, revision work and so on.
- Approach for the support: Dispatch of experts to related ministry and department, short-term training in Japan
- Support effect or the mark: Obligated items and discharge standards in respect of mine environment and safety are presented and responsibilities of relevant persons are clarified.
- A possible duration of the support: 2-3 years.

(2) Support for Establishment of Inspection and Monitoring Method in respect of Mine Environment and Safety - #1

➢ Main object countries: Angola, Zambia, Malawi, Botswana, Zimbabwe, Mozambique and Madagascar

- Content of the support: Launch of working group for the preparation of procedure manual of the approach, participation in the working group, technical guidance, preparation work, participation in the inspection and monitoring, and so on.
- Approach for the support: Dispatch of experts to related ministry and department, short-term training in Japan
- Support effect or the mark: Management approach such as audit work for operating and abandoned mine, consideration work for countermeasure based on the monitoring work are clarified by persons in charge.
- A possible duration of the support: 2-3 years.

(3) Support for Establishment of Inspection and Monitoring Method in respect of Mine Environment and Safety - #2

➢ Main object countries: Zambia

- Content of the support: Establishment of the Center for Mine Environment and Safety, initial management for the Center and follow-up for the initial management of the Center.

- Approach for the support: Technical support, loan assistance, science and technology cooperation, and dispatch of experts to related ministry and department
- Support effect or the mark: The Center will became a stronghold and a project model for the sustainable mining in Southern Africa Region. The Center would be monitored mining project and operating mine in the eyes of mine environment and safety.
- A possible duration of the support: 6-7 years.

(4) Support for Short- and Long-Term Training

➢ Main object countries: Basically all 8 countries (Angola, Zambia, Malawi, Botswana, Zimbabwe, Mozambique, South Africa and Madagascar).

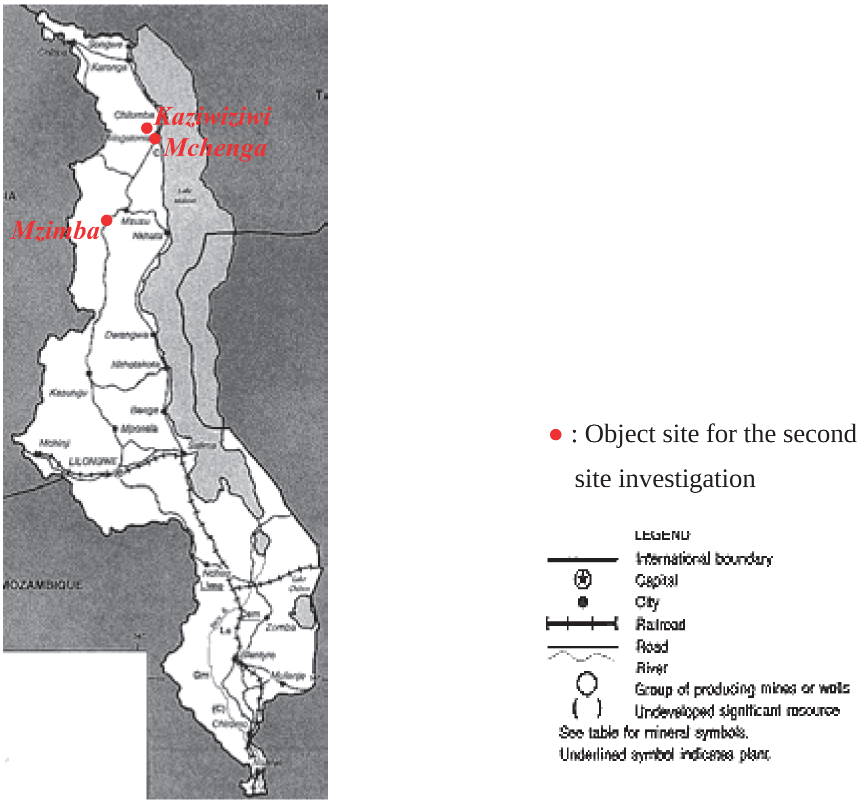
- Content of the support: Training for management of sustainable mineral resources development and for eco-friendly efficient resource development and the use, technical acquisition for related terrain, site visit to related site in Japan, study for mine environment field (water, soil and air, etc) and ore processing field (mining, dressing, smelting and so on) in Japan.
- Visitation site in Japan: Operating metal mine (ex: Hishikari Au), Geothermal power plant (ex: Onuma), Smelter (ex: Naoshima Cu, Hyuga Ni), Abandoned mine facilities (ex: Matsuo S, Myoho Cu), Recycle facilities (ex: Kosaka), Utilization facilities for closed mine site (ex: Sado Au, Ashio Cu), countermeasure facilities against mine pollution (ex: Watarase Pond).
- Approach for the support: Participation to training for specific area through JICA (mining, environment management, etc), participation to seminar for exploration and environmental conservation by METI/JOGMEC, related site training at visiting sectors in Japan, study through long-term in University using by ABE Initiative.
- Support effect or the mark: Hoard of basic and applied knowledge in respect of related area.
- A possible duration of the support: 2-3 years.

5.2.2. Support for the Second Investigation Site

Based on the consideration derived in the second site investigation, future direction of the support for the sites are recommended as bellow.

(1) Malawi

Possible directions of support for Mchenga coal mine, Kaziwiziwi coal mine, Small-scale mines and aggregate mines in the Malawi are described as bellow (Figure 5.5).



(Map form USGS)

Figure 5.5 Support relating to Mine Environment and Safety in Malawi

a. Mchenga Coal Mine

➢ Matter of Concern (Mine environment): Acid mine drainage is flowing into stream from abandoned pit. Several collapses are observed on the abandoned pit and large-scale landslide and flooding of acid drainage caused by heavy rain are concerned

- Content of the support: Countermeasure construction to improve direct effluence and collapse of the acid mine drainage.
- Content of the countermeasure: Construction work for drainage canal, protection dike, slope protection, land grading and stabilization around the abandoned pit.
- Support effect or the mark: The matter of concern will be solved in the countermeasures and the related organizations will be able to manage the concern in the future.
- Approach for the support: Technical support and loan assistance
- A possible duration of the support: 2-3 years.

➢ Matter of Concern (Mine safety): Space between walkway and belt conveyer is not enough for the operation due to the narrow in the pit. Accident contact with the belt conveyer and worker is easy to occur in the place. Additionally, rock fallings are easy to occur in the pit situation where there are no enough poling boards under the roof.

- Content of the support: Technical assistance and countermeasure construction in respect of the space use and rock falling protection in the pit.
- Content of the countermeasure: Designing of layout for the pit space and set of pillars and poling boards.
- Support effect or the mark: These supports become direct support for protection of accidents.
- Approach for the support: Technical support and loan assistance
- A possible duration of the support: 2-3 years.

b. Kaziwiziwi Coal Mine

➢ Matter of Concern (Mine environment): Mine drainage including coal particles from coal washing plant flows in sediment pond and the slag in the drainage is deposited in the pond. These drainage and slag have been overflowed at the time of heavy rain, which situation is concerned direct effluence to the river.

- Content of the support: Countermeasure construction in respect of the protection for the overflow of drainage and slag from the sediment pond.
- Content of the countermeasure: Construction work for bank protection of the sediment pond and the drainage canal relating to the sediment pond
- Support effect or the mark: The matter of concern will be improved in the countermeasures and the mine will be able to manage the concern in the future.
- Approach for the support: Technical support and loan assistance
- A possible duration of the support: 2-3 years.

c. Small-Scale Mine such as Gemstone mines in Mzimba

➢ Matter of Concern (Safety): Land shape of the pit shows trench-like where the miners are digging by their hand. Depth of the open place reaches more than dozen meters. Rain water deposits in the open pit during rain season. Related miners of the small mines are hired by the day, which they do not have PPE and are conducting the digging in the unsafe condition.

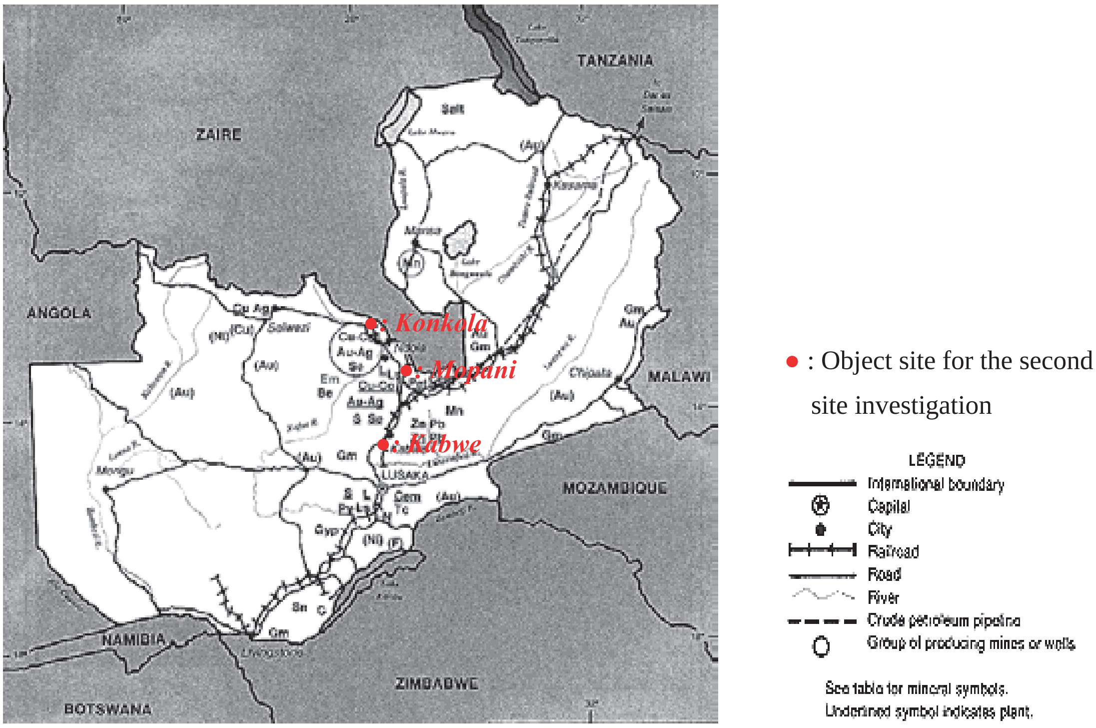
- Content of the support: Safety training for to wear PPE and to set up protection fence and related matters.
- Content of the countermeasure: Construction work for bank protection of the sediment pond and the drainage canal relating to the sediment pond
- Support effect or the mark: The condition of safety will be improved.
- Approach for the support: Technical support.
- A possible duration of the support: 1-2 years.

d. Small-Scale Mines such as Aggregate mines

- ➢ Matter of Concern (Mine environment and safety): Dusts form the face and stock yard in the mine site become complaints from inhabitants around the mine and the employees are potentially harmful to health by the dusts. Additionally, the site is pointed out flaws in PPE and protection fence.
  - Content of the support: Training for nonproliferation and health of the dusts, and for to wear PPE and to set up protection fence and related matters.
  - Support effect or the mark: The condition of work and safety environments will be improved.
  - Approach for the support: Technical support.
  - A possible duration of the support: 1-2 years.

(2) Zambia

Possible directions of support for Kabwe abandoned Zinc-lead mine, Mopani copper mine and Konkola copper mine in the Zambia are described as bellow (Figure 5.6).



(Map form USGS)

Figure 5.6 Support Relating to Mine Environment in Zambia

a. Kabwe Abandoned Zinc-lead Mine

- ➢ Matter of Concern (Mine environment): Metal contents of water and soil in river, drainage and ground around the former mine show high. Also, some reports suggest that the lead content in blood of the children have relatively high as well. The water and soil are used for livelihood, farming and so on which the effects are concerned about the rerated environment.
  - Content of the support: To study to clarify the pollution mechanism and the detail, to make a

master plan in respect of the management, to conduct restoration work based on the master plan.

- Content of the countermeasure: Construction work for former tailing dam, slag dumps, drainage canal, sediment pond, protection fence and planting for related area.
- Support effect or the mark: The pollution will be improved in the countermeasures and the related organization will be able to manage the concern in the future.
- Approach for the support: Technical support, loan assistance and science and technology cooperation.
- A possible duration of the support: 4-5 years.

b. Mopani Copper Mine

➢ Matter of Concern (Mine environment): Metal contents of water and soil in river, drainage and ground around the former mine show a little bit. The water and soil are used for livelihood, farming and so on which the effects are concerned about the rerated environment. However, these contents have kept under the effluent standards by the environmental law.

- Content of the support: To study to clarify the pollution mechanism and the detail, to consider the countermeasures, to conduct restoration work based on the consideration.
- Content of the countermeasure: Construction work for drainage canal around mine area and tailing dam.
- Support effect or the mark: The concerns will be improved in the countermeasures and the mine will be able to manage the concern in the future.
- Approach for the support: Technical support, loan assistance and science and technology cooperation.
- A possible duration of the support: 4-5 years.

c. Konkola Copper Mine

➢ Matter of Concern (Mine environment): Metal contents and pH of the water well around tailing dam show relatively high content and low pH. The water has used for livelihood and farming in which the effects are concerned about the rerated environment.

- Content of the support: To study to clarify the pollution mechanism and the detail, to consider the countermeasures, to conduct restoration work based on the consideration.
- Content of the countermeasure: Construction work for drainage canal around mine area and tailing dam.
- Support effect or the mark: The concerns will be improved in the countermeasures and the mine will be able to manage the concern in the future.
- Approach for the support: Technical support, loan assistance and science and technology cooperation.
- A possible duration of the support: 4-5 years.

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Conclusion of this study are summarized as follows;

(Summary of the Study)

- Objectives of the Study consist of 1) compilation of existing condition and data collection on the mine environment and safety, 2) examination of information on the superiority of mine environmental technology owned by Japanese companies and organizations and to be usable to objective countries, and 3) investigation of the request on capacity development and personnel training.
- The objective countries consist of eight countries including Angola, Zambia, Malawi, Botswana, Zimbabwe, Mozambique, Madagascar and South Africa.
- The Study is composed of five steps, namely the Preparation work in Japan, First Site Investigation, Analysis work in Japan, Second Site Investigation and Compiling work in Japan.
- The First Site Investigation, consisting of collecting data and information on the mine environment and safety, holding of Seminar, request of the personnel training of each country, was carried out in one month between November 11, 2013 and December 8, 2013.
- Malawi and Zambia were selected as places for Second Site Investigation by consideration work in Japan after the First Site Investigation. The sites consist of three coal mines and small-scale mine for gems in Malawi, and two copper mines and one abandoned zinc-lead mine in Zambia. Finally, actual number of the objective sites reached eight sites.
- The Second Site Investigation was conducted i) environment investigation, ii) soil sampling and analysis, iii) water sampling and analysis, iv) simple survey, and v) inspection for occurrence of pollution, scale of the pollution, mine environment, arrangement of issues, consideration of countermeasure of mine pollution control and current situation about mine environment and safety.
- After the Second Site Investigation, comprehensive work was carried out to extract issues, to integrate information and to recommend several support projects for the future.

Based on the collecting information during site investigations, current situations in respect of mine environment and safety for objective countries are summarized as follows;

(Mine Management and Legislation related to the Mine Environment)

- Each country had newly instituted or revised in 1990's to 2000's in order to aim a promotion of mining development as well as a sustainable development of mineral exploration and exploitation of minerals.
- mining policies were shifted from mining depend on only specified minerals such as Au,

diamond, etc. to the mineral exploration and exploitation of various kinds of mineral resources such as base metals, rare earth elements (REE) and energy resources (petroleum, natural gas and coal).
- Several countries and areas still have problems of infrastructure building for the mine development and occur difficult to promote a foreign investment for the mineral exploration and exploitation.

(Mining Condition)

- In South Africa, Zimbabwe and Zambia, various kinds of mineral resources has been historically developed for a long time.
- In other countries, the development of mineral resources was relatively recent and further mineral exploration and mine development are expected because of high potential of mineral resources. Particularly, active mineral exploration and a few copper mines have been developed in the southwestward extension areas from the Copper Belt, located along the boundary between Zambia and Democratic Republic of the Congo, in Angola and Botswana (called as Kalahari Copper Belt).

(Environmental Policy and Environmental Condition)

- The environmental legislation, including Environmental (Basic) Law, Environmental Protection Act, etc., has mostly instituted in each country. The environmental impact assessment is mostly regulated within the Environmental (Basic) Law, and the Ministry of Environment is enforced to formulate the environmental policy.
- The evaluation of environmental impact assessment concerning the mineral exploration and exploitation in the Ministry of Environment of the objective countries are entrusted to the ministry in charge of mining. However, staff in charge of environmental evaluation concerning the mining in each country are luck of practical experiences, therefore it is necessary to formulate and enforce a long-term personnel training.
- Concerning the environmental protection such as an environmental management and monitoring plans, project enforcement person in most of countries has a responsible to carry out the environmental obligation according to the Mining Law. However, monitoring enforcement system in whole area of each country is not built yet, thus environmental condition including environmental pollution, hot spots, etc. in each objective country is not comprehended yet.
- Environmental standards for air quality, water quality, soil quality, noise and vibration, etc. had mostly set up in objective countries, however a few environmental items are not set up in some countries. Therefore, it is necessary fully to install the environmental standards for the environmental evaluation.

(Mine Pollution, its Potential and Measures)

- Mine development of sulfide ore deposits such as base metals is rare in Angola, Malawi and Mozambique, therefore ore pollution is presently not found in these areas. However, those areas have also potential of mine pollution.

- Other countries can be found mine pollutions such as acidic wastewater from mine sites, exhaust gas from smelters, etc. and much influence to the environment downwards. However, the environmental investigation and mitigation against the mine pollution is inefficient.
- It is necessary to carry out environmental investigation by monitoring for understanding the environmental condition and formulate the technical guidelines, etc. for countermeasures and those enforcement.

(Chemical Analysis)

- Public laboratory under the ministry related to the environment or mining is not established in Angola and Mozambique, but under consideration. In other countries, the public laboratory is established under the Geological Survey or Ministry of Environment.
- Concerning the analytical accuracy and components, the laboratory related to the Environment mostly aims environmental analysis, and the laboratory related to the Geological Survey mostly aims environmental analysis purposes to analyze ore mineral, geochemical exploration and inorganic analysis.
- The Laboratory under the Environmental Management Agency in Zimbabwe carries out monitoring investigation and is planning to establish database of analytical results.

(Mine Safety)

- Statistic on disaster and accident in mines and smelters had been obtained in Botswana and Zimbabwe, but those of other countries was not obtained.
- Concerning the mine safety, ministry and government agency in charge of each country are supervising operating mines such as ministerial direction, order, etc. without practical training for the mine safety. However, technical training of mine safety is periodically enforced by the Chamber of Mines in Zimbabwe.

(Personnel Training and Request of Technical Training)

- Each country has not specified personnel training program.
- Requests from relevant ministries and agencies of each country to JICA are covered a wide range of categories, many persons and various period of training.

6.2 Recommendations

On the basis of challenges in the each country that were obtained information relating to mine environment and safety during study, recommended supports in eight countries and plans for improvement and countermeasure in Zambia and Malawi were described in the Chapter 5.

Based on collected information by this study, the current aspects of mining sectors in objective countries are divided into three situations as follows;

i) Resources country or country of relatively developed within mineral resources production (South Africa, Angola, Botswana, Zambia and Zimbabwe)
ii) Developing country within mineral resources production (Malawi and Madagascar)
iii) Country standing midway between relatively developed country and developing country within the mineral resources production (Mozambique)

Among these, countries belonging to the above i) have specific concerns and challenges on mine environment and safety, which immediate countermeasures or handling are required. On the other hand, countries belonging to ii) and iii) do not have critical issues in respect of mine environment and safety, however the countries are needed for preparation about to improve laws and to upgrade skills for person in charge for the future. In addition, Madagascar is thought to be belonging to the ii), which the country has large-scale mines such as Amvatovy Nickel Mine and Mandena Ilmenite Mine. However, their current stand relating to mine environment and safety as an audit side are assumed as unstable situation due to lack of their standards in respect of the permission works.

Based on the above situations in the objective countries, future projects are proposed as follows;

(Zambia)

<u>Program</u>: Construction work for countermeasure of mine pollution at around Kabwe Abandoned Zinc-Lead Mine

- Situation relating to the countermeasure: Zinc and lead contents of water and soil in river, drainage and ground around the former mine show high. The former tailing dam was basically backfilled by slag and waste of previous mine. These residual materials are easy to flow out under the influence of erosional and wind process. Zinc and lead contents of water and soil around former mine and along the downstream show high content. Based on this situation, these components have a probability of diffusion to around the former mine already. Additionally, there are no protection fence around the former mine lots, inhabitants are easily able to inter the area. For the former mine water flowing around former mine, inhabitants have been used for domestic use water in the downstream. The area to be needed for the countermeasure is approximately 2km x 2km.

- Content of the countermeasure: The countermeasure items are grading, replanting and installation of protection fence at the former dumps, construction of sediment pond, and construction of drainage canals at downstream. Contamination concerns will be reduced by the countermeasures and the related organization will be able to manage the pollution in the future. If these countermeasures will be commenced the constructions, the works should be proceeded to take a step-by-step approach due to the scale of the countermeasure works are comprised of small and large scale. Among these, construction work of the sediment dam corresponds to the biggest scale in the works. For such reason, comprehensive countermeasure plan is needed to being before the work. Prospective time frames of the construction works are 4-5 years for sediment dam, 2-3 years for drainage canal and 1-2 years for others. The budget scales for the constructions are estimated as dozens of hundred million yen in total, dozens of million to hundreds of million yen for the sediment dam, hundreds of million yen for the drainage canal and tens of million to hundreds of million yen for the other constructions.

  Clarification of the pollution mechanism is needed for above construction work before the commencement. For the interpretation, analysis for soil and water by boring survey and simulation for groundwater flow are needed for the clarification. The budget scales for the clarifications are estimated as approximately tens of million yen.
- Conducting of training: Site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

  Additionally, abandoned Sado Au Mine and Ashio Cu Mine are recommended as visiting sites for to learn the knowledge how to utilize abandoned mine. These abandoned mines have tourist facilities and scenic parks as a recreational facility for public.

<u>Program</u>: Construction work for improvement of drainage water from mine facilities at Mopani and Konkola Mine in Copperbelt
- Situation relating to the improvement: Metal contents of water and soil in river, drainage and ground around each mine show a little bit high in part of the site. Also seepages from the tailing dam of each mine are observed in near the dam, which these seepages are directly flowed in the river. Among this, water quality from water well at near the dam of Konkola Mine shows acidic feature in the pH. Inhabitants near the well have been using the water as a domestic use water. The area to be needed for the countermeasure is approximately 2km x 2km.
- Content of the improvement: Upgrade and new construction for the drainage canals around mine facilities and tailing dam are needed for the improvement. The improvement also needs groundwater flow analysis before the upgrading.

Prospective time frames of the improvement works are 2 years for the drainage canals and 3-4 years for the new construction. The budget scales for the constructions are estimated as hundreds of million yen or tens of million yen for the improvement and hundreds of million yen for the new construction.

For the groundwater analysis, analysis for soil and water by boring survey and simulation for groundwater flow are needed for the clarification. Prospective time frame of the work will be taken 2 years. The budget scales for the clarifications are estimated as approximately tens of million yen.

- Conducting of training: Site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

  Additionally, abandoned Sado Au Mine and Ashio Cu Mine are recommended as visiting sites for to learn the knowledge how to utilize abandoned mine. These abandoned mines have tourist facilities and scenic parks as a recreational facility for public.

Program: Country-by-Country training for countermeasure construction in respect of mine environment

- Background of the training: Mining development in Zambia has been very active. On the other hand, there are concerns about improvement and countermeasure relating to the mine environment and the related persons are well understanding this situation. However, the improvement and construction works are still not quite advanced enough yet at the moment. For example, rehabilitation plan for the Kabwe abandoned mine has not commenced the construction works so far.

  For above situation, participation of parsons in charge to the training is useful for considerations about the sustainable mining in the country.
- Conducting of training: Site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

  Additionally, abandoned Sado Au Mine and Ashio Cu Mine are recommended as visiting sites for to learn the knowledge how to utilize abandoned mine. These abandoned mines have tourist facilities and scenic parks as a recreational facility for public.

(Malawi)

Program: Training and construction work for countermeasure at Mchenga Coal Mine

- Situation relating to the countermeasure: Acid mine water has flowed from in the stream and collapses of the ground are also observed on the pit. These features are concerned about to occur landslides including acid water during heavy rain and rain season. Settlements locate in downstream of the same catchment. For this, if the landslide happened from the concerned site, the slide is able to occur disaster. The area to be needed for the countermeasure is approximately hundreds of meter x meter.
- Content of the countermeasure: Construction work to improve outflows of acid mine water and prevention of the collapse of ground are needed for the countermeasure. The items of the actual work consist of construction of discharge canal, protection dike and slope protection, and land-cleaning and grading, and so on. In the training, countermeasure construction will be carried out during the training and the lectures instruct the method of countermeasures and construction management as well.

  Both construction for outflow prevention of mine water and collapse of the ground are needed for the countermeasure. Time flame will be taken 2 or 3 years and the budget scale estimated at a hundred million yen.
- Conducting of training: Site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

Program: Training and improvement work of mine safety at Mchenga Coal Mine

- Situation relating to the improvement: Space in the pit has basically 3m x 2.5m and the width of the pit becomes narrow at the deeper part in the pit. Belt conveyor is used for the transport of coal from face in the pit. However, the space between walkway and belt conveyer is not enough for the operation due to the narrow in the pit. Accident contact with the belt conveyer and worker is easy to occur in the place. Additionally, rock fallings are easy to occur in the pit situation where there are no enough poling boards under the roof. Based on the above, area for the improvement covers main pit and mine facilities.
- Content of the improvement: The items consist of technical guidance, and countermeasure construction in respect of the space use and rock falling protection in the pit. Among these, designing of layout for the pit space and set of pillars and poling boards are needed for the improvement. In the training, improvement construction will be carried out during the training and the lectures instruct the method of improvement and construction management as well.

Time flame for the improvement construction will be taken 2 or 3 years and the budget scale estimated at tens of million or a hundred million yen.

- Conducting of training: Training in respect of safety are needed to be held in the site and Lilongwe, which experts having experience of management at coal mine should be dispatched from Japan as lecturers. Based on this, related persons are able to obtain knowledge and method of management relating to upgrading of the technologies of mine safety.

(Madagascar)

Program: Acquisition of techniques for audit and monitoring of mine environment and safety

- Situation relating to the acquisition: Related persons in the government side have been suggesting that existing laws in respect of mine environment and safety are not corresponded to actual situation in the related terrain of the recent date, which there are no original standards for effluences. On the other hand, there are no manuals for method of the audit and monitoring to preserve related laws. Among these situations, judgments by audit side have became unstable on processes for related permission such as EIA. The situation are especially noticeable in the case of large-scale mines and the facilities, which mines were commenced their operation in recent years.
- Conducting of training: The acquisitions by training are performed in Japan. Items of the training consist of basics of mine environment and safety, standards of environment and safety relating to audit and monitoring, and method and procedure of audit and monitoring. Additionally, site visit at treatment facilities for mine water of abandoned mines in Japan are recommended as a training. This will be enable them to learn method of the countermeasure and to manage and monitor the concerns. During the training, actual water monitoring work using by portable equipment are also recommended as a learning. Abandoned Matsuo S Mine and Myohoho Cu Mine are envisioned for the possible site of the training.

  Besides the above, Hishikari Au Mine, Naoshima Cu Smelter and Hhuga Ni Smelter as actual operating metal mine and facilities are recommended as visit sites, which related trainees are able to obtain basic knowledge of mining.

Program: Support for upgrading of related laws in respect of mine environment and safety

- Situation relating to the upgrading: As noted above, related persons in the government side have been suggesting that existing laws in respect of mine environment and safety are not corresponded to actual situation in the related terrain of the recent date, which there are no original standards for effluences. On the other hand, there are no manuals for method of the audit and monitoring to preserve related laws. Among these situations, judgments by audit side have became unstable on processes for related permission such as EIA. The situation are especially noticeable in the case of large-scale mines and the facilities, which mines were commenced their operation in recent years. Ministry of Mines and

National Office of Environment are well recognized need to upgrade as audit side. Among these, Directorate of Mines has requested the upgrading of related laws and procedures to this study.

- Content of support: This program supports to revisions of laws relating to current mining and environmental laws and creations of procedures relating to audit and monitoring. I this program, revisions of laws and regulations with consideration for the management of mine closure, revisions of standards for related matters, and upgrading for current audit and monitoring are included in the support.