Republic of Cameroon

FY2021 Ex-Post Evaluation Report of Technical Cooperation Project

"The Project on Magmatic Fluid Supply into Lakes Nyos and Monoun and Mitigation of Natural Disasters through Capacity Building in Cameroon"

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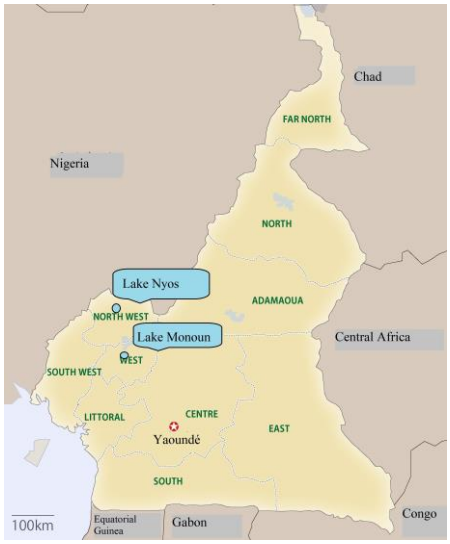
0. Summary

This project was implemented to establish a framework where Cameroonian scientists can independently accomplish their own research on the issues related to the gas disasters at Lakes Nyos and Monoun through international joint research between Japan and Cameroon involving scientists from Institute of Geological and Mining Research (hereinafter referred to as "IRGM"), thereby disseminating information to local population on gas disasters and disaster prevention using IRGM's research results in collaboration with IRGM and Division of Civil Protection (hereinafter referred to as "DPC").

The objectives of this project were consistent with the policy priorities of the government of Cameroon; in light of the recognized need to monitor the amount of residual CO_2 continuously in the target lakes. Therefore, the relevance of the project is high. In addition, the objectives of this project aligned with Japan's ODA policy for Cameroon, with other JICA projects in disaster prevention management, and with other organizations that ensured the installation of degassing pipes and monitoring of the effects of degassing. Therefore, coherence is high. Although the project's international joint research produced a number of publications, the underutilization of IRGM's analytical equipment limited the achievement of the project's purpose, "independent research on limnic eruptions by Cameroonian researchers." In addition, the project's effectiveness and impact have been moderately low; this is reflected in the absence of significant results of the researchers' efforts to disseminate the project's gas disaster research results to the local population. Although delays in the disbursement of counterpart funds and equipment provision affected the achievement of some outputs, the project period and costs on the Japanese side were within the plan. Therefore, efficiency of the project is high. Although slight technical issues have emerged in the current operation and maintenance of the equipment, there are good prospects for improvement/resolution, the equipment which is currently out of service will be utilized and the monitoring of the lakes and sample analysis are expected to resume through the follow-up cooperation consisting of equipment procurement and dispatching engineers for the lake degassing system and lake water monitoring scheduled in FY2022. Therefore, sustainability of the project effects is high.

In light of the above, this project is evaluated as satisfactory.

1. Project Description



Project Location(s)

Deep lake water discharged from a degassing pipe installed in Lake Nyos
(source: https://www.jica.go.jp/oda/project/1000710/index.html)

1.1 Background

In northwestern Cameroon, massive emissions of carbon dioxide (CO2) from Lake Monoun (in 1984) and Lake Nyos (in 1986) caused disasters that took the lives of many residents and livestock. The 1984 Lake Monoun explosion killed 37 people, and the 1986 Lake Nyos explosion killed 1,746 people and about 3,000 livestock. The area around Lake Nyos was closed to habitation, and the roads passing nearby were closed to traffic. Under these circumstances, by request of the government of Cameroon, technical cooperation project was implemented as Science and Technology Research Partnership for Sustainable Development (hereinafter referred to as “SATREPS”) from April 2011 to March 2016 by IRGM as the counterpart research institution and Tokai University as the representative of the Japanese research institution.

1.2 Project Outline

Overall Goal[1]		In collaboration with IRGM and DPC's jurisdiction over disaster management, disseminate information to local residents about gas disasters and disaster prevention using IRGM's research results.
Project Purpose[2]		A framework is established where Cameroonian scientists can independently accomplish their own research on the issues related to the gas disasters at Lakes Nyos and Monoun through science and technology cooperation between Japan and Cameroon.
Output(s)	Output 1	The mechanism of limnic eruption is understood.
	Output 2	The CO2 recharge system beneath Lakes Nyos and Monoun is understood.
	Output 3	The hydrogeological regime around Lakes Nyos and Monoun is understood.
	Output 4	The interaction between rock and in the CO2-rich fluid is understood.
	Output 5	Lakes Nyos and Monoun are monitored.
	Output 6	The experimental system for removing CO2-rich deep water to prevent gas rebuilding at Lake Monoun is set up.
	Output 7	Magmatism of Oku volcanic zone is understood.
	Output 8	Geochemical parameters of lakes along Cameroon Volcanic Lines (CVL) other than Nyos and Monoun are understood.
	Output 9	The results of scientific monitoring are systematically shared with DPC.
Total cost (Japanese Side)		420 million yen
Period of Cooperation		April 2011-March 2016
Target Area		Lakes Nyos and Monoun
Implementing Agency		IRGM
Other Relevant Agencies/ Organizations		Ministry of Economy, Planning and Regional Development (MINEPAT), Ministry of Territorial Administration (MINATD), Ministry of Scientific Research and Innovation (MINRESI), DPC
Organization in Japan		Tokai University (principal research institution), University of Tokyo, Osaka University, University of Toyama, Kumamoto University, Tokyo Institute of Technology
Related Projects		＜Projects of Other Donors> • *Security and Socio-Economic Reintegration of Lake Nyos Area* (UNDP, EU, 2008-2013) • *Natural Disaster Management and Civil Protection Projec*t (AFD) • *Lake Nyos Dam Reinforcement Project* (EU)

[1] Since no overall goal was set for this project, the evaluator analyzed the project information, proposed the above as the overall goal, and obtained the approval of the parties concerned.

[2] The project purpose, as stated in the Project Design Matrix (PDM), is "a framework is estab1ished where Cameroonian scientists can independently accomplish their own research on the issues related to the gas disasters at Lakes Nyos and Monoun and utilize its outcomes for disaster management through scientific cooperation between Japan and Cameroon." After achieving the project purpose, the SATREPS project aims for the social implementation of research results as an overall goal. In the ex-post evaluation, the evaluator interpreted the project purpose of PDM "utilize [the project's] outcomes for disaster management" as equivalent to social implementation, evaluated this (rather than the stated project purpose) as the overall goal, proposed this interpretation to the parties concerned, and obtained their approval.

1.3 Outline of the Terminal Evaluation

1.3.1 Achievement Status of Project Purpose at the Terminal Evaluation

The project purpose was expected to be achieved to some extent. Out of the initial five indicators, two (communication, fundraising through acceptance of analytical request with charge) were achieved, and three (preparation of operational directions, appropriate use of observation and analysis equipment, and systematic storage of water and rock samples) were partially unachieved.

Regarding the operational directions, most of the simplified users' manuals were prepared, but Standard Operating Procedures (SOPs) for monitoring activities were not ready yet by the project's end. Some main analytical equipment such as an Atomic Absorption Spectrometer (AAS),[3] an isotope analyzer (Picarro),[4] a carbon isotope analyzer (13C Analyzer)[5] and multibeam sonar data processing were considered underutilized. It was expected that the unachieved indicators would be achieved by completing the instruction manual and conducting additional training on some analytical equipment in the remaining project period.

For the "systematic storage of water and rock samples," IRGM designed the storage, and Japanese experts provided advice on cataloging samples. Achievement of this indicator was expected only if the storage was renovated with funding from the World Bank.

1.3.2 Achievement Status of Overall Goal at the Terminal Evaluation

No overall goal was set for this project. If the project's findings on the mechanism of lake explosions were successfully shared with residents living near the lakes, the impact of the project's social implementation would be relatively high.

1.3.3 Recommendations from the Terminal Evaluation

(1) Measures to be taken by the termination of the project

- Disbursement of the remaining counterpart funds:

  MINEPAT and the Ministry of Finance were strongly requested to ensure the

[3] Equipment that analyzes minute amounts of metallic cations dissolved in water, used to analyze harmful heavy metals present in groundwater. The development of water resources is an important social issue in Cameroon, and many requests for sample analysis are expected if this equipment operates smoothly (source: documents provided by JICA).

[4] Equipment used to estimate the origin of water by analyzing the isotope ratio of hydrogen and oxygen. The isotope analyzer is indispensable for water quality surveys and for hydrological surveys aimed at water resource development. Once the equipment is operating smoothly, many requests for sample analysis are expected (source: documents provided by JICA).

[5] Equipment used to estimate the origin of CO2. It is possible to identify CO2 originating from magma, which is essential for monitoring volcanic activity (source: documents provided by JICA).

disbursement of the remaining amount of the counterpart funds, as expenditures only reached 60% of their planned amount.

- Follow-up for unachieved indicators:

Completion of monitoring activities' SOP was required. For the proper use and maintenance of the provided equipment, the number of analytical request orders would increase and IRGM technicians would obtain additional training in the use of the main equipment.

- Return of inputs to outputs:

Because only one of the five long-term trainees belonged to IRGM at the time of the terminal evaluation, it was desirable to act to ensure that the capacities of long-term trainees would be fully utilized for lake monitoring and disaster reduction activities.

- Improving sustainability:

In order to sustain the project's outcomes, it is indispensable to maintain and develop capacities built through the project and the network established by the project, including those connecting Japanese researchers and long-term trainees.

(2) Measures to be taken after project completion

- Utilization of the project outcomes:

Relevant stakeholders in Cameroon, including IRGM, were strongly recommended to secure the necessary funding to continue monitoring, take an additional measure for degassing, and utilize the outcomes generated by the project to ensure the safety of the lakes.

- Strengthening of organizational capacity:

So that they may effectively utilize the knowledge and technology gained throughout the project, IRGM was encouraged to further strengthen their organizational capacity. Specific recommendations included setting up mechanisms for sharing knowledge within the institute (e.g., holding regular seminars, preparing operational directions, and continuing regular meetings between IRGM headquarters and the laboratory) and ensuring the allocation of financial and human resources for lake monitoring and data analysis.

- Sharing of monitoring data among the project's research members:

The data generated from lake monitoring is valuable for the research members involved in the project. To generate additional scientific results from data utilization, the project's research members were encouraged to continue sharing the collected data with each other after the project ends.

- Strengthening disaster risk reduction framework:

Setting up an effective framework among stakeholders was recommended to strengthen disaster risk reduction after the project's completion.

2. Outline of the Evaluation Study

2.1 External Evaluator

Maki Hamaoka, Foundation for Advanced Studies on International Development

2.2 Duration of Evaluation Study

This ex-post evaluation study was conducted with the following schedule.

Duration of the Study: November 2021-December 2022

Duration of the Field Study by Local Consultant: March 2022-July 2022

2.3 Constraints during the Evaluation Study

(1) Since October 2017, numerous clashes have occurred between Anglophone separatist groups advocating independence and the security authorities in English-speaking regions, including the North-western regions in which Lake Nyos is located. The conflict has resulted in numerous casualties, including civilian casualties. There have also been incidents of kidnapping and murdering foreigners and, as of the ex-post evaluation, for the travel to this region, the travel cancellation advisory issued by the Ministry of Foreign Affairs of Japan is still in effect. Even for Cameroonians, travel to the above region remained dangerous. Therefore, the local consultant was unable to confirm the status of Lake Nyos on site. Moreover, the survey on information dissemination to the local people formerly living in the Lake Nyos neighborhood was conducted in Bamenda City, where many of the former residents now reside, but the difficulty of finding participants for workshops organized by the project during its implementation limited the scope of interviews.

(2) With regard to Lake Monoun, local people were dissatisfied with the project, believing that the government of Cameroon was prioritizing Lake Nyos in terms of disaster countermeasures. Residents took action to manifest their dissatisfaction by cutting the cables of the meteorological station that the project installed in Lake Monoun. During the ex-post evaluation, the local consultant visited Lake Monoun and interviewed local people with military escort, but encountered difficulty in obtaining information from them.

3. Results of the Evaluation (Overall Rating: B[6])

3.1 Relevance/Coherence (Rating: ③[7])

3.1.1 Relevance (Rating: ③)

3.1.1.1 Consistency with the Development Plan of Cameroon

At the time of the ex-ante evaluation, the government of Cameroon set forth its method of disaster prevention, “development of economic infrastructure and natural resources,” as

[6] A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory

[7] ④: Very High, ③: High, ②: Moderately Low, ①: Low

the fourth of six axes described in the *Poverty Reduction Strategy Paper* (2003). In addition, in recognition of the gas disaster in Lake Nyos as an important issue, the government of Cameroon worked on degassing the lake water and assisting victims under the initiative "*National Program for the Rehabilitation and Security of the Nyos Zone*" (2008).

At the time of the project completion, it was not possible to confirm the position of disaster prevention and gas disasters in the Cameroonian government's development plan in the "*Growth and Employment Strategy Paper"* (2009), the successor policy of the Poverty Reduction Strategy Paper. However, given that the "*National Program for the Rehabilitation and Security of the Nyos Zone*" continued, it can be assumed that the government of Cameroon prioritized measures against gas disasters as part of its policy even at the time of project completion.

In light of the above, since efforts to prevent disasters through gas disaster research continued as a national program from the start to the completion of this project, this project was in line with the Cameroonian government's policy priorities.

3.1.1.2 Consistency with the Development Needs of Cameroon

As mentioned above, at the time of the ex-ante evaluation, the area around Lake Nyos and Lake Monoun had suffered many casualties and serious social and economic impacts; residents were living in evacuation shelters, and the main roads around Lake Nyos were closed. This project met Cameroon's social needs by mitigating human and social damage caused by magmatic fluid supply into lakes by providing scientific knowledge obtained from research and monitoring to disaster prevention efforts. In addition, only three lakes in the world have been found to cause gas disasters, making those described here unique. Although foreign researchers have conducted research on the circumstances of such disasters in the past, the mechanism has not been fully elucidated. In addition, foreign researchers took data out of the country, and the training of Cameroonian researchers who could independently continue research and monitoring was not progressing. Since the supply of CO_2 to the lakes continues, it was necessary to develop a system that allows Cameroonian researchers to conduct continuous and independent research and monitoring and human resource development through this project was consistent with Cameroon's needs.

The result of the measurement of the amount of CO_2 remaining in both lakes during the project implementation showed that after the installation of two additional degassing pipes in 2011, the amount of CO_2 in Lake Nyos started to decrease quickly with a rate of 1.44 Gmol/year, which was doubled after 2013 when 3 pipes started working. However after 2014, the amount decreased by a third (0.5 Gmol per year). At Lake Monoun, the amount of CO_2 remaining in the lake bottom increased from 2011 to 2014, and decreased in 2015. Since the change in the amount of CO_2 in both lakes was unpredictable, regular monitoring of the

lakes was necessary at the time of the project completion.

In light of the above, from the time of ex-ante evaluation to the time of project completion, it can be judged that this project was consistent with Cameroon's development needs.

3.1.1.3 Appropriateness of the Project Plan and Approach

Though guidelines for environmental and social considerations were not applied at the time the project was requested, it was formulated with consideration for the socially vulnerable. This consideration was intrinsic in its attention to the safety of the Lake Nyos and Lake Monoun areas, forced to evacuate due to gas disasters.

In this project's plan and approach, the following appropriateness issues emerged.

The outputs and project purpose in the narrative summary of the PDM used for the project implementation lacked logical organization. In addition, some of the indicators of the project purpose and outputs were not suitable as indicators for accurate evaluation of the objectives indicated in the project summary and it was difficult to evaluate the project according to the PDM. Therefore, the ex-post evaluation reviewed the indicators for the overall goal, the project purpose, and the outputs.

As described later in Section 3.2.2 Impacts, no results of the social implementation (i.e., the utilization of research results for disaster prevention) were confirmed at the time of the ex-post evaluation. Despite the lack of preparation for social implementation pointed out in the mid-term review, detailed components were not formulated at that time. Furthermore, at the time of the terminal evaluation, a framework for post-project social implementation did not yet exist. Accordingly, the fact that a system for social implementation was not established during the project explained the absence of results of such an initiative at the time of the ex-post evaluation.

Although the above-mentioned issues were found, the parties involved in this project could not have had a concrete image of social implementation because this project was an early SATREPS project. Ultimately, the project's expectations and execution did not differ considerably, as it generated many international joint research products, such as published papers and international conference presentations. Therefore, the appropriateness of the project plan and approach did not factor into the evaluation of the project's relevance.

3.1.2 Coherence (Rating: ③)

3.1.2.1 Consistency with Japan's ODA Policy

The priority areas of assistance to Cameroon in JICA's rolling plan (2009) were (1) human

resource development, (2) economic development, and (3) farming and fishing/rural development. This project was aligned with these priority areas as it aimed to contribute to the autonomy of Cameroon's researchers as well as to regional and economic development through improving disaster management around Lake Nyos and Lake Monoun.

In January 2005, the Japanese government announced the "*Initiative for Cooperation in Disaster Risk Reduction*" as a basic policy for assisting developing countries reduce their disaster risk through ODA. The policy mentioned using technology to observe and predict the danger of disasters, and supported human resource development related to technology for disaster risk assessment.

Furthermore, Japan has advocated the necessity and importance of strengthening diplomacy and utilizing ODA to facilitate science and technology cooperation. To strengthen cooperation in science and technology, the Cabinet Office's Council for Science and Technology Policy compiled "*Towards Strengthening Science and Technology Diplomacy*" (April 2007, May 2008), and "*Innovation 25*" (June 2007) which focused on developing countries.

In light of the above, the objectives of this project were well-aligned with Japan's ODA policy and the science and technology policies of the Japanese government.

3.1.2.2 Internal Coherence

One representative of IRGM and one representative of DPC participated in JICA's thematic training "Community Disaster Risk Reduction," held in Kobe from June 22 to August 1, 2015. In February 2016, the two representatives implemented the action plan prepared in the training by leading a workshop for the residents of the areas around Lakes Nyos and Monoun. At the workshop, the mechanism of limnic eruptions and the actions to be taken in the event of a limnic eruption as the research results of this project were explained. In this regard, the interconnection between this project and the training program was confirmed.

3.1.2.3 External Coherence

The government of Cameroon formulated the "*National Program for the Rehabilitation and Security of the Nyos Zone*" to ensure safety around Lake Nyos, return displaced persons to their hometowns, and revitalize the region. With this program, the government launched a five-year *Project for Security and Socio-economic Reintegration of Lake Nyos Area* with the support of the UNDP and the EU. The addition of two degassing pipes in this program was a pillar of the Lake Nyos disaster countermeasures. Degassing pipes were being procured at the time of the ex-ante evaluation. The plan of the program did not include observation and monitoring after the degassing pipes were set up, but the installation's

outcome was monitored in Output 5 of this project.

In addition, the French government (through the *Natural Disaster Management and Civil Protection Project*) and the EU (through the *Lake Nyos Dam Reinforcement Project*[8]) assisted in mapping risk zones, designing regulatory regimes, and formulating disaster prevention plans to improve disaster prevention and emergency response capabilities in the areas around Mount Cameroon and Lake Monoun. These projects had no particular collaboration with this project.

This project was consistent with the development plan and development needs of the government of Cameroon. In terms of coherence, the objectives of this project were well-aligned with Japan's ODA policy and assistance policies for Cameroon at the time of the ex-ante evaluation. Concrete evidence of the project's cooperation with JICA's other projects and with other aid agencies is apparent in the cooperation between this project and the JICA training scheme, in the installation of degassing pipes, and in the subsequent monitoring of the effect of degassing. Therefore, its relevance and coherence are high.

3.2 Effectiveness and Impacts[9] (Rating: ②)

3.2.1 Effectiveness

As mentioned in Section 2.3 Constraints during the Evaluation Study, the PDM used during the project implementation had some logical weaknesses in the project summary and indicators. Therefore, in the ex-post evaluation, the evaluator reviewed the indicators by organizing these into an Input-Outputs-Outcomes structure, as shown in the figure below.

[8] A project to construct a facility to properly drain the lake water when the water level rises in order to prevent the collapse of the natural dam that forms the rim of Lake Nyos (source: detailed planning survey report)
[9] When providing the sub-rating, Effectiveness and Impacts are to be considered together.

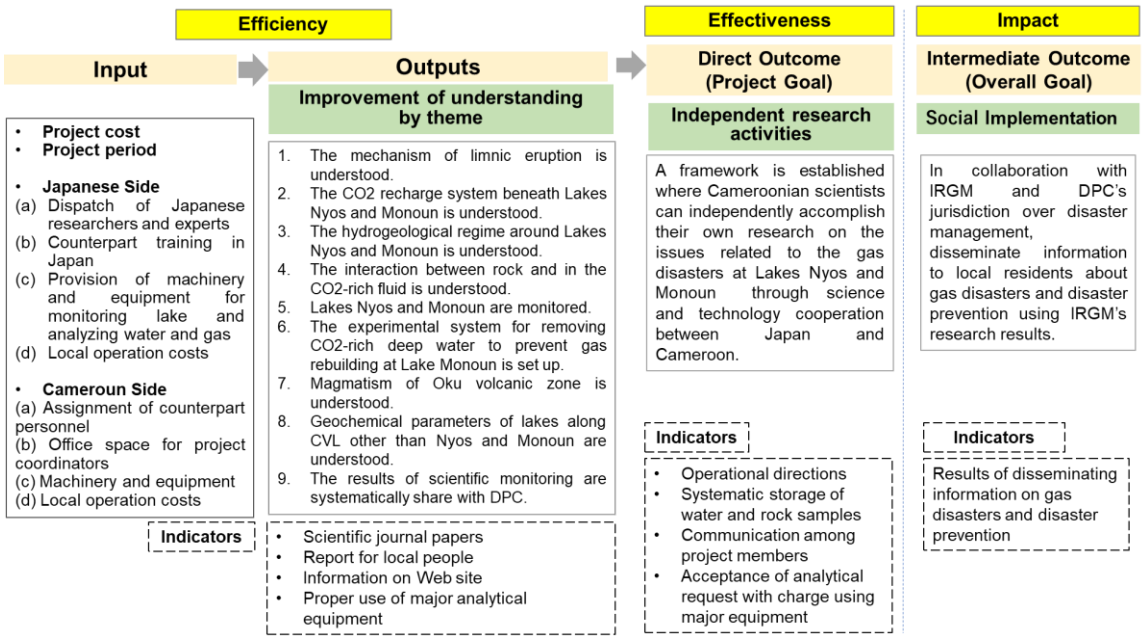


Figure 1 Logic of the Project as Organized in the Ex-Post Evaluation

Source: Prepared by the evaluator on the basis of the terminal evaluation report and answers to the questionnaire

3.2.1.1 Project Output

As shown in the project logic diagram above, one of the indicators of the initial project purpose, "appropriate use of equipment," is not an indicator of the revised project purpose, but rather an indicator of the conversion of input (provision of equipment) to output (proper use of the provided equipment). Evaluation focused on the appropriate use of four main items, used for acceptance of analytical request with charge and particularly important among the equipment provided by this project. The four items are (1) ion chromatograph (IC), (2) 13C Analyzer, (3) AAS, and (4) Picarro.

The achievement of each output is shown below (see Appendix 1 for the achievement status for each output).

- By the end of the project, Japanese experts and Cameroonian researchers had produced 31 scientific journal papers. One of these papers was published by *Scientific Report*, which belongs to Nature Publishing Group, thereby enhancing the reputation of Cameroonian scientists.
- These papers resulted from international joint research that strengthened the ability of IRGM researchers and technicians to observe lake water and analyze data and deepened their understanding of the mechanisms of lake explosions and the process of supplying carbon dioxide to lakes through the dispatch of Japanese experts, training in Japan, and provision of equipment.

- Due to the equipment's delayed provision and eventual malfunction, IRGM technicians were not able to use three of the four main pieces of analytical equipment independently and properly at the time the project was completed.

Table 1 Usage of Major Equipment at the Time of Project Completion

Equipment	Status
IC	・ Utilized without technical problems by IRGM staff
AAS	・ At the time of installation in December 2013, the manufacturer technician instructed the IRGM technicians on the operation. Installation of the equipment was delayed 2 years and 8 months after the start of the project. ・ From October to November 2014, a special researcher at Tokai University intensively instructed IRGM technicians on using the AAS. Furthermore, an IRGM researcher who had come to Japan as a long-term trainee at Tokai University learned how to operate the AAS at a manufacturer in Japan. ・ The AAS broke down in 2015 and was out of service for 6 months. At the time of terminal evaluation, the counterparts answered that they were not confident in their ability to use the equipment.
Picarro	・ When the project started, Picarro operated without any problems, but has been out of service for at least 2 years due to electrical and maintenance problems.
13C Analyzer	・ The equipment was provided in December 2014, 3 years and 8 months after the start of the project. In addition to this delay, it was not used outside training due to the lack of gas samples required for analysis.

Source: Prepared by the evaluator based on the terminal evaluation report

3.2.1.2 Achievement of Project Purpose

Table 2 shows the degree of achievement of project purpose at the time of the project completion.

Table 2 Achievement of Project Purpose

Project Purpose	Indicator	Actual	Achievement Level (Sub-Rating)[Note]
A framework is established where Cameroonian scientists can independently accomplish their own research on the issues related to the gas disasters at Lakes Nyos and Monoun through science and technology cooperation between Japan and Cameroon.	Indicator 1: An operational direction in IRGM including the following contents • Lake observation • Lake, spring, well, rain water and river sampling • Water analysis • Gas analysis • Accreditation of analytical equipment	<Almost achieved> • At the time of the terminal evaluation, most of the simplified users' manuals for the major analytical equipment had been prepared, but SOPs on lake monitoring had not yet been prepared. At the time of the terminal evaluation, it was recommended that the IRGM prepare SOPs based on the monitoring that had been carried out, and revise them as necessary. • At the time of the follow-up survey conducted in January 2020, the SOP issue no longer existed at IRGM. The survey mission determined that follow-up on SOPs was unnecessary. • SOPs were not prepared, but this did not impede IRGM's monitoring activities. • Researchers accumulated the necessary knowledge during the project implementation and instructions for gaining further knowledge. However, no instructions have been prepared for the purpose of knowledge transfer.	③

	Indicator 2: Systematic storage of water and rock samples	<Achievement was limited> • The PDM indicates that this indicator can be verified by the presence of "shelves in the building of the laboratory for storing well-catalogued (GIS ref) water and rock samples." However, since it is not possible to check the achievement status only with the shelves, the evaluator verified IRGM staff's ability to store water and rock samples systematically. • The project prepared a design for sample storage in the basement of IRGM's laboratory. The storage was to be renovated within the "*Projet de Renforcement des Capacités dans le Secteur Minier (Project for Capacity Building in the Mining Sector)*", funded by the World Bank. However, the project was transferred from IRGM to the Ministry of Mines and Energy, and the sample storage was not refurbished. • During the project implementation, the Japanese experts made catalogs of collected water and rock samples, organized the samples, and stored them. However, IRGM counterparts were not aware of systematic storage at the time of the ex-post evaluation. Japanese researchers gave advice, but there were no specific activity records related to technology transfer on systematic storage, so the achievement of this indicator appears limited.	②
	Indicator 3: Communication among the project team members	<Achieved> • The PDM indicated this indicator to be verifiable by "use of a groupware through Internet." The ex-post evaluation confirmed achievement by interpreting the intention of the indicator as information sharing and exchange of opinions among project members or IRGM researchers, rather than simply the use of groupware.[10] • The mid-term review included recommendations for improved communication among project members. Since the mid-term review, monthly meetings have been held between IRGM headquarters, laboratory representatives, and the project coordinator to share information and discuss project matters among project members. • At the time of the terminal evaluation, communication among project members had greatly improved. Although groupware was not used, communication improved in various ways through mailing lists, websites, and seminars.	③

[10] The mid-term review conducted in 2013 pointed out that the lack of internal meetings in the project may have affected the smooth implementation of activities and, in turn, the outputs. Therefore, it was necessary to hold regular meetings with all project members, including project managers, researchers, engineers, and operational staff, to share information, discuss, make decisions, solve problems, and implement feedback. In addition to the above, the review recommended that communication and networking strengthen not only between representatives of the Japanese and Cameroonian sides, but also between researchers by effective use of means such as the internet and e-mail. Considering these recommendations, the evaluator in the ex-post evaluation interpreted the indicator to measure an improvement in communication among project members regardless of means.

	Indicator 4[11]: Acceptance of analytical request with charge using major equipment	< Achievement was limited > • IRGM staff was unable to use three of the four main analytical equipment independently by the project's completion. As a result, analytical request with charge was limited (see Table 3). In particular, Picarro and AAS were not used for analysis other than for practice purposes during project implementation and other research projects (see Table 4).	②

Source: Prepared by the evaluator based on the terminal evaluation report, answers to the questionnaire by the implementing agency, and answers to the questionnaire by the former experts.
Note: ④: Indicators were achieved more than planned, ③: achieved mostly as planned, ②:achieved to a limited extent, ①:not achieved

Table 3 Number of Acceptance of Analytical Requests with Charge

		←During the project implementation (April 2011–March 2016)→					←After the project completion (after March 2016) →					
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Universities	51	21	7	37	128	342	366	185	218	4	38	117
SATREPS	0	0	0	0	30	72	0	0	0	0	0	0
Others	131	147	131	149	280	236	152	451	174	122	137	209
Total	182	168	138	186	438	650	518	640	392	126	175	326

Source: Documents provided by the implementing agency

Table 4 Number of Samples Analyzed by Equipment

Item	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IC	0	0	30	650	518	636	392	126	175	326
AAS	-	-	0	0	0	4	0	0	22	11
Picarro	(10)	0	0	(10)	0	0	0	0	0	0
^{13}C Analyzer	0	0	0	0	0	0	0	0	0	0

Source: Documents provided by the implementing agency

The project achieved its purpose only to a certain extent: two out of four indicators (preparation of operational directions, communication) were achieved or almost achieved, but two indicators (systematic storage of water and rock samples, acceptance of analytical request with charge using major equipment) were not achieved. Among them, the acceptance of analytical request with charge using major equipment, which is considered to be of relatively high importance for the project purpose of "independent research on the issues related to the gas disasters at Lakes Nyos and Monoun," had limited achievement due to delays in the procurement of equipment and preparation of laboratory facilities. This hindrance affected the expected proper use of the provided equipment, an output described in Section 3.2.1.1 Project Output.

[11] Initially, the indicator was "proper use of each analytical and observational instrument" but in the ex-post evaluation, it was reorganized as an indicator at the output level; accordingly, the project purpose to be achieved through the outputs changed to "analytical request with charge using major equipment".

3.2.2 Impacts

3.2.2.1 Achievement of Overall Goal

Achievement of the overall goal is limited, as shown in Table 5.

Table 5 Achievement of Overall Goal

Overall Goal	Indicator	Actual
In collaboration with IRGM and DPC's jurisdiction over disaster management, disseminate information to local residents about gas disasters and disaster prevention using IRGM's research results.	Results of disseminating information on gas disasters and disaster prevention	<Achievement is limited> ・ The Nyos and Monoun Community Enhancement for Disaster Risk Awareness workshop was held in February 2016 with the main objectives of raising awareness of the actual situation regarding gas disasters in the targeted lakes, increasing disaster prevention knowledge with 137 participants in Zoa City (Lake Nyos) and 145 participants in Kouoptamo City (Lake Monoun). The workshop was conducted as an action plan developed by two participants of the 2015 JICA thematic training "Community Disaster Management". Participants of the workshop were provided with a leaflet to raise local people's awareness, which the project had compiled into an easy-to-understand, illustrated guide to the mechanism of lake explosions and the actions to take in an emergency.[12] 7,000 leaflets were produced, and after the workshop, the remaining 6,500 leaflets were planned for use by the two participants of the above-mentioned thematic training to continue the action plan. However, the action plan was not continued due to the departure and resignation of the two participants. At the time of the ex-post evaluation, the remaining 6,500 leaflets were stored at DPC (400), JICA Cameroon Office (10), and IRGM (the remainder). ・ Since the change of DPC Director in 2016, little collaboration has occurred between IRGM and DPC. ・ In March 2022, the local consultant for this ex-post evaluation interviewed 15 residents, six in Bamenda, near Lake Nyos, and nine in Kouoptamo, near Lake Monoun. Four of the residents were confirmed to have participated in the above workshop and they explained the contents of the leaflet at village residents' meetings, women's meetings, and to their families after the workshop, but no information related to the lake explosion by the IRGM or DPC appeared to have been disseminated since the project was completed in March 2016.

Source: Prepared by evaluator based on answers to questionnaires from the implementing agency and field survey results by the local consultant

[12] The parties involved in the project were asked about the number of leaflets they distributed, but no information was obtained.

3.2.2.2 Status of Outputs and Project Purpose

As shown in Table 6, joint research between IRGM and several Japanese research institutes in various fields has continued since the completion of the project. The results of the joint research continue to emerge, with 30 papers published after the completion of the project.

Concerning observation of the lakes, security issues have made it difficult to monitor both Lake Nyos and Lake Monoun, and various activities, including monitoring, have not been carried out.[13]

The analytical request with charge increased in the latter half of the project implementation, and although it turned to decrease from 2018 to 2020, it has been increasing since 2021 (see Table 3).

Table 6 Status of Outputs after Project Completion

Outputs	Status after Project Completion to Ex-Post Evaluation
Output 1 The mechanism of limnic eruption is understood.	<The effect of the output continues> • In 2017, three papers were published jointly by Japanese and IRGM researchers.
Output 2 The CO2 recharge system beneath Lakes Nyos and Monoun is understood.	<The effect of the output continues> • Paper published in 2017 • Joint research continues with research funds from Osaka University. • CO2 monitoring method is utilized for disaster prevention purposes.
Output 3 The hydrogeological regime around Lakes Nyos and Monoun is understood.	<The effect of the output continues> • Submission to an international journal by the University of Tokyo • Presentation at an international conference by the University of Tokyo
Output 4 The interaction between rock and the CO2-rich fluid is understood.	<The effect of the output continues> • Information on CO2 gas emission simulation code is exchanged between University of Toyama and IRGM.
Output 5 Lakes Nyos and Monoun are monitored.	<Limited continuation of effects> As for Lake Monoun, the weather station has not been used since the cable was cut by a nearby resident during the project implementation. At Lake Nyos, the IRGM has not been able to confirm the status of the equipment due to the unrest in the North-western region.
Output 6 The experimental system for removing CO2-rich deep water to prevent gas rebuilding at Lake Monoun is set up.	<The effect of the output continues> • The experimental system for removing CO2-rich deep water installed at Lake Monoun broke down in 2017, but it was repaired by IRGM and it is still in use as of 2022. • One paper was published in 2017.

[13] Lake Monoun did not pose a security problem, but the local people were dissatisfied with the government because they perceived the safety of Lake Nyos as a priority, and they interfered with IRGM's monitoring activities on Lake Monoun. In fact, at the time of the ex-post evaluation, the local consultant was escorted by soldiers, and it was not possible to interview the local population calmly.

Output 7 Magmatism of Oku volcanic zone is understood.	<The effect of the output continues> • Joint research is continuing under the Grants-in-Aid for Scientific Research. • One paper was published in 2018 and one in 2019. • After the completion of the project, the IRGM researcher was employed as a postdoc for one year at the Earthquake Research Institute of the University of Tokyo. After returning to Cameroon, he led the research on continental mantle plumes and the training of young researchers at the Ministry of Mineral Resources, Industry and Technology Development. He has returned to Japan as a visiting researcher at the Earthquake Research Institute of the University of Tokyo for one year from October 2020, and continues joint research.
Output 8 Geochemical parameters of lakes along the CVLs other than Nyos and Monoun are understood.	<The effect of the output continues> • Joint research continues with research funds from Kumamoto University.[14] • Joint research is continuing under the Grants-in-Aid for Scientific Research. • Associate professors of Ibaraki University and IRGM researchers are continuing joint research under the visiting researcher/visiting professor system of the Earthquake Research Institute of the University of Tokyo.
Output 9 The results of scientific monitoring are systematically shared with DPC.	<The effect does not last> Refer to Section 3.2.2.1 Achievement of Overall Goal

Source: Prepared by the evaluator based on documents provided by JICA and answers to the questionnaire from the implementing agency

Based on the above, the scientific knowledge obtained through project implementation continues to be jointly researched with the research institutes in charge of each field, and results such as co-authored papers and conference presentations continue to occur. However, regarding the social implementation of returning research results to local residents, the effect was not expressed, because the implementation system and specific plans for implementing social implementation were not sufficiently considered during the project implementation, and after the project completion, the relationship between IRGM and DPC became weak. In light of the above, the achievement of the overall goal was only confirmed to a certain degree compared to the plan.

3.2.2.3 Other Positive and Negative Impacts

1) Impacts on the Natural Environment

At the time of the project request, the guidelines for environmental and social considerations were not applied to this project. No impact on the natural environment was reported at the time of the ex-post evaluation.

[14] Source: Documents provided by JICA

2) Resettlement and Land Acquisition

This project did not involve resettlement and land acquisition. In November 2013, explanatory meetings were held for residents in Wum City (Lake Nyos) and Kouoptamo City (Lake Monoun) to disseminate information to residents from the perspective of disaster prevention. In February 2016, workshops were held with the aim of raising awareness about the actual situation of gas disasters, disaster prevention knowledge, and emergency measures.

3) Gender Equality, Marginalized People, Social Systems and Norms, Human Well-being and Human Rights and Others

None

4) Unintended Positive/Negative Impacts

The eruption transition model of the maar volcano presented in the research by the Kumamoto University group (Elucidation of the history of eruptive activity around the volcanic lakes of the CVL) is being used in the ongoing comprehensive activity evaluation of volcanoes in Japan and the disaster prevention project. In addition, the model contributes to next-generation volcano research and the human resource development project of Ministry of Education, Culture, Sports, Science and Technology.

Since this project has achieved its purpose to some extent and overall goal only to a certain extent, effectiveness and impacts of the project are moderately low. For the project purpose, the level of achievement was limited because "acceptance of analytical request with charge" which is considered highly important among the indicators for the purpose of "independent research," was not sufficient, and specific results of “systematic storage of water and rock samples” was not confirmed. Regarding the achievement of the overall goal, it is judged that the expected effects have not been realized because IRGM and DPC have not established a system to disseminate information on the lake explosion in cooperation, and the research results have not been returned to the local population.

3.3 Efficiency (Rating: ③)

3.3.1 Inputs

Inputs	Plan	Actual
(1) Experts	• One long-term expert (project coordinator) • Approximately 12 short-term experts/year × 5 years (chief advisor, experts in geochemistry, volcanology, petrology, geology, geography, hydrology, etc. dispatched multiple times; MM is not specified)	• Long-term experts: three in total (project coordinator 56.79 MM) • Short-term experts: 15 short-term researchers in six fields, 29.93 MM
(2) Trainees received	Trainings for acquisition of a degree, acquisition of analysis equipment/operation/maintenance training, etc. (No information on the number of persons)	• Five persons for long-term training • 15 persons in total for short-term training
(3) Equipment	Equipment for monitoring lakes and analyzing water and gas samples	119 items for monitoring lakes and analyzing water and gas samples
(4) Local Operational Cost	Not specified	120 million CFA francs (Approx. 24.6 million yen)
Japanese Side Total Project Cost	Total 420 million yen	Total 420 million yen
Cameroon Side Total Project Cost	850 million XAF* (Approx. 175 million yen[15])	557 million XAF (Approx. 111.4 million yen)

* MM stands for man month.

* XAF is the ISO code of Central African CFA franc, which is the currency of six independent states in Central Africa, including Cameroon.

3.3.1.1 Elements of Inputs

Regarding the dispatch of experts, according to a questionnaire survey of counterparts at the time of the mid-term review, the period for which Japanese researchers were dispatched was not long enough for them to learn to operate the provided analytical equipment and the daily analysis work. About half of the respondents strongly requested long-term dispatch to receive training that is more detailed. Furthermore, in the questionnaire surveys and interview surveys conducted at the terminal evaluation, many counterparts answered that the number and duration of the dispatches of Japanese experts were limited. It is possible that the limited period of dispatch was a factor in the lack of sufficient mastery of some of the major equipment.

Regarding the trainees received, the researchers and technicians who participated in the short-term training program were able to acquire knowledge on the operation and maintenance of the same analytical instruments provided by the project through lectures and practical training, and they recognized the importance of sample management through visits

[15] The exchange rate was 1 Japanese yen = 4.7787 XAF (October 9, 2015) (source: terminal evaluation report, p.4)

to various laboratories in Japan. It was confirmed that the knowledge acquired through such practical training was utilized in the laboratory even after the training,[16] and it can be said that the short-term training was an input that led to outputs.

As for the long-term training, all five researchers, including one IRGM researcher, obtained a doctoral degree within three years of their dispatch and published several high-quality papers during their dispatch, contributing significantly to the achievement of Outputs 3, 7, and 8. One of the papers was published in a *Nature*-affiliated journal (*Scientific Report*). Of the five long-term trainees, one who was affiliated with IRGM at the time of dispatch continued to work at IRGM after returning to Cameroon. Of the remaining four, two were employed by IRGM and one is continuing his research at MINRESI, the parent organization of IRGM. Thus, all of the long-term trainees have demonstrated their achievements in researching lake explosions.

With regard to equipment, some of the equipment needed for lake observations and analysis of water and rock samples was not fully utilized. Although some of the reasons were unavoidable, such as falling into the lake or cables being cut by nearby residents, others were due to input from the Cameroonian side, such as problems with the laboratory's infrastructure (electrical system problems).

3.3.1.2 Project Cost

The total project cost borne by the Japanese side was 420 million yen representing 100% of the total amount budgeted.

The Cameroonian side was supposed to disburse 850 million CFA francs (about 175 million yen) as counterpart funds over a five-year period, but disbursements were made only twice, in 2011 and 2015, totaling 557 million francs, or 65.5% of the planned amount. According to the Cameroonian side, the difference between the planned and actual disbursement of counterpart funds was due to (1) late disbursement due to overload of work at the MINEPAT, which was in charge of counterpart funds, and (2) emergencies (Boko Haram measures and response to flooding in the northern region) that affected the distribution of treasury funds. Due to the delay in counterpart funding, one of the planned activities (geological mapping) and a field survey by IRGM were not carried out.[17]

3.3.1.3 Project Period

The actual project period was five years representing 100% of the total planned period.

Although delays in the disbursement of counterpart funds and the provision of equipment

[16] Source: Mid-term Review Report, vi
[17] Source: Terminal Evaluation Report, p.20

affected the achievement of some outputs, such as the utilization of equipment, the project period and the project costs on the Japanese side were within the plan. Therefore, efficiency of the project is high.

3.4 Sustainability (Rating: ③)

3.4.1 Policy and System

In 2022, the government of Cameroon launched a comprehensive research project, *the Lake Monoun Project*, targeting Lake Monoun.[18] IRGM is involved in the project on the scientific side as a member of the pilot committee that monitors and analyzes the data. With the launch of *the Lake Monoun Project*, it was confirmed that research on volcanic lake gas would continue institutionally. Therefore, it is judged that the sustainability of policies and systems is high.

3.4.2 Institutional/Organizational Aspect

At the time of the ex-post evaluation, IRGM has a staff of 284, of which 165 are researchers and 25 are technicians. The government of Cameroon has hired new young researchers in IRGM in recent years, and there is no quantitative shortage.[19] At the time of the ex-post evaluation, 14 of the 26 counterparts of the project are still with IRGM, seven had retired, and five had transferred to other related organizations, including MINRESI. Many of the counterparts continue to conduct research on volcanic lake gases and volcanoes as well as lead the training of young researchers. In addition, retired researchers are continuously mentoring IRGM researchers, thus knowledge and skills are being passed on from senior researchers to young researchers.

Regarding communication within the IRGM, no problems exist because meetings between IRGM executives and researchers are held monthly and internal meetings are held as needed. In addition, IRGM is making efforts to disseminate research results by holding an open day once a year for external audiences and holding seminars on an irregular basis.

Regarding the system for social implementation, as mentioned in Section 3.2.2.1 Achievement of Overall Goal, there is no collaboration between IRGM and DPC, and no mechanism or system has been established to disseminate research results on the mechanism of lake explosions and information on disaster prevention.

Because the main objective of this project is to conduct independent research on volcanic

[18] The contents of the project are as follows: “monitoring of the physico-chemical properties of Lake Monoun,” “installation of two photovoltaic pump systems,” “microbiological and ecological studies of Lake Monoun and other lakes in its vicinity,” “quantification of surface CO2 fluxes in and around Lake Monoun,” “Installation of meteorological stations and CO2 warning systems in and around Lake Monoun,” “construction of the Panke River weir and evaluation of water quality in the catchment area,” and “creation of 1:25,000 scale geological map around Lake Monoun” (source: documents provided by JICA).

[19] Source: Answers to the questionnaire from the implementing agency

lake gases, the ex-post evaluation focused on the system for this purpose. As a result, it is judged that IRGM has sufficient human resources to continue its research and observations in the future, no communication problems exist, and the sustainability of the institutional/organizational aspect is high.

3.4.3 Technical Aspect

As previously mentioned in Section 3.2.2.2 Status of Outputs and Project Purpose, IRGM has not conducted observation activities and monitoring in either Lake Nyos or Lake Monoun due to security issues, and it has not collected any observation data. In addition, even with regard to operational equipment, some equipment, such as the multibeam sonar, requires further technical training by IRGM, and other equipment, such as Picarro, is currently inoperable and needs to be investigated by the U.S. manufacturer (Picarro) to correct the problem and make it operational. Thus, for IRGM to resume monitoring and analyses that have been interrupted, or to put non-operational equipment back into operation and accept sample analyses from external parties, it is necessary to improve the operational and analytical capabilities of analytical equipment further.

A follow-up survey of the project was conducted from January to February 2020. The follow-up survey was conducted to examine follow-up cooperation to improve IRGM's ability to operate the equipment, strengthen the operation and maintenance system of the equipment, and ensure the sustainability of activities using the equipment, because there were variations in the level of understanding of operation of equipment and data analysis among IRGM technicians. As a result of the follow-up survey, JICA plans to procure equipment and dispatch engineers to restore the lake's gas venting system and lake water monitoring as follow-up cooperation in FY2022.

Based on the above, the IRGM's technical capacity to observe the lake independently and analyze samples is not sufficient at this time, but technical sustainability is expected to improve through follow-up cooperation scheduled for implementation in FY2022.

3.4.4 Financial Aspect

The sectoral budget allocation of the Cameroonian government was confirmed from the government's national budget data over time: From FY2011 to FY2015, 0.6-0.7% of the national budget was allocated to scientific research and innovation. Since the completion of the project, this percentage has decreased somewhat.[20] In addition, as shown in Table 7, the IRGM's overall budget has been declining since FY2015, and due to budget shortfalls, hazard maps, water resource maps, and soil maps have not been prepared. Regarding the budget, the government of Cameroon has prioritized the allocation of funds to the response

[20] Source: Documents collected by the local consultant

to the deteriorating security situation in the Northwest and Southwest regions due to clashes between the separatists who claim independence of English-speaking regions and security forces, and to the response to the new coronavirus, which has affected scientific research and budget allocation for the IRGM. This was considered an external factor in the ex-post evaluation.

If the number of analytical requests with charge using analytical equipment increases after the follow-up cooperation scheduled for FY2022, the financial aspect of the project is expected to improve.

Table 7 Budget of the IRGM

		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Current budget (Total)		2,170,162,029	1,746,595,000	2,607,532,788	5,439,526,811	1,861,521,663	1,460,788,109	1,379,620,804	1,581,694,657	1,323,939,576	1,393,645,147	1,887,000,430	1,125,000,000
(1)	Running budget	689,876,626	686,697,000	670,000,000	555,284,378	587,408,512	600,804,484	622,047,235	688,714,701	503,695,716	552,773,513	619,909,196	500,000,000
	Structure												
01	Directorate	144,520,000	139,701,000	143,733,500	132,605,262	143,132,148	134,324,484	151,510,000	151,310,000	130,950,000	165,987,000	176,898,000	177,692,000
	Shared expenses	339,232,826	345,775,000	329,610,500	273,654,853	284,845,000	299,668,050	311,147,235	247,012,552	149,740,716	204,854,320	242,674,196	155,925,000
02	*CRGM*	50,050,000	53,420,000	57,020,000	50,230,000	50,945,000	50,090,000	53,750,000	68,400,000	46,930,000	26,735,000	48,000,000	30,420,000
03	CRH	60,500,000	62,620,000	64,190,000	48,616,090	51,760,000	50,110,000	47,110,000	46,337,149	36,660,000	36,310,000	30,570,000	28,660,000
05	LTM	50,476,000	45,540,000	48,140,000	32,683,483	37,055,000	40,310,000	38,960,000	38,820,000	31,220,000	29,070,000	27,700,000	25,300,000
04	LRE	39,869,000	40,271,000	42,386,000	31,635,490	34,468,364	30,502,000	28,360,000	28,160,000	22,460,000	18,335,000	14,915,000	18,267,000
06	LTI	35,278,800	35,790,000	36,640,000	27,089,200	31,610,000	27,210,000	23,810,000	24,310,000	19,010,000	16,777,193	15,662,000	17,816,000
07	*ARGV*	40,865,000	46,370,000	57,840,000	55,380,000	50,630,000	56,478,050	51,400,000	66,265,000	47,725,000	35,005,000	43,990,000	27,920,000
08	Tenders board	20,000,000	17,000,000	5,300,000	9,000,000	4,538,000	18,679,950	20,150,000	18,100,000	18,000,000	18,700,000	19,500,000	17,000,000
09	Management under the Program	0	0	0	0	0	0	1,000,000	0	1,000,000	1,000,000	0	1,000,000
(2)	Equipment and Investment	1,480,285,403	1,059,898,000	1,937,532,788	4,884,242,433	1,274,113,151	859,983,625	757,573,569	892,979,956	820,243,860	840,871,634	1,267,091,234	625,000,000

Source: Documents provided by the implementing agency

3.4.5 Environmental and Social Aspect

No environmental and social impacts were observed from the time of planning to the time of post-evaluation.[21]

3.4.6 Preventative Measures to Risks

The deterioration of security in the North-western and South-western regions since 2017, which affects the continuation of observations and monitoring of Lake Nyos, is a risk that was not foreseen at the time of planning, and is not a risk that the IRGM can address. As mentioned above, the sustainability of the project's outcome of independent study of lake explosions will be ensured by the resumption of at least the lake degassing system and lake monitoring in Lake Monoun through follow-up cooperation in FY2022.

3.4.7 Status of Operation and Maintenance

[21] Source: Answers to the questionnaire from the implementing agency

As with the 2020 follow-up survey, the maintenance status of the equipment at the time of the ex-post evaluation was confirmed, focusing on expensive equipment (see Table 8). In the field survey at the time of the ex-post evaluation, in addition to the equipment listed in Table 8, unused reagents and test equipment were found in cardboard boxes.

Table 8 Status of the Operation and Maintenance of the Equipment

No*	Item	Status	Remarks
1	IC	In use	
3	MK sampler 1	In use	
4	MK sampler 2	Not being used	Due to insecurity in the Lake Nyos area, the IRGM is not able to determine the current state of the equipment.
8	CTD logger	In use	The one procured by the project fell into the lake. IRGM procured the same equipment with its own funds.
13	Picarro	Not being used	
14	Desktop pH meter	Not being used	Battery leakage
15	Pure water maker	n.a.	
18	Multibeam sonar system	In use	As in the follow-up survey, IRGM needs more training on how to use the equipment.
29	CO2 flux meter	In use	
34	Thermometer	Not being used	
43	Alumina magnetic mortar	Not being used	At the time of the follow-up survey and ex-post evaluation, the equipment was kept in a cardboard box in storage.
86	13C Analyzer	In use	At the time of the follow-up survey, the equipment was not in use because IRGM was not able to prepare its in-house reference material (calcium carbonate), which should be calibrated against international reference material. Calcium carbonate can be prepared at the time of the ex-post evaluation, but it is not used because there are not many requests for sample analysis.
87	Polarization microscope	In use	
91	AAS	In use	
93	Graphite nebulizer for AAS	In use	
94	Standard water for isotope analysis	Not being used	Not working because Picarro is not working
96	Digital camera for Microscope	In use	
98	Volumetric titrator	In use	

Source: Prepared by the evaluator based on answers to the questionnaire from the implementing agency
* The number of the equipment list at the time of equipment provision

When equipment breaks down, IRGM purchases spare parts and repairs. Because most of the equipment provided by this project is highly precise, some parts cannot be replaced or repaired immediately. If IRGM technicians are unable to repair a device, then IRGM takes appropriate measures such as contacting the manufacturer online or requesting an agency to dispatch engineers.

From the above, although there is no problem in that IRGM technicians are responding appropriately even if they are unable to repair equipment failures, the reagents and equipment necessary for analysis remain unused. It seems that issues with the status of

operation and maintenance exist.

Slight issues have been observed in the technical and the current status of operation and maintenance, however, there are good prospects for improvement/resolution, in that the main equipment will be utilized and the lake observation and sample analysis is expected to resume through the follow-up cooperation consisting of procurement of equipment and dispatch of engineers for degassing system of the lake and resumption of monitoring of the lakes scheduled in FY2022. Therefore, sustainability of the project effects is high.

4. Conclusion, Lessons Learned and Recommendations

4.1 Conclusion

This project was implemented to establish a framework where Cameroonian scientists can independently accomplish their own research on the issues related to the gas disasters at Lakes Nyos and Monoun through international joint research between Japan and Cameroon involving scientists from IRGM, thereby disseminating information to local population on gas disasters and disaster prevention using IRGM's research results in collaboration with IRGM and DPC.

The objectives of this project were consistent with the policy priorities of the government of Cameroon; in light of the recognized need to monitor the amount of residual CO2 continuously in the target lakes. Therefore, the relevance of the project is high. In addition, the objectives of this project aligned with Japan's ODA policy for Cameroon, with other JICA projects in disaster prevention management, and with other organizations that ensured the installation of degassing pipes and monitoring of the effects of degassing. Therefore, coherence is high. Although the project's international joint research produced a number of publications, the underutilization of IRGM's analytical equipment limited the achievement of the project's purpose, "independent research on limnic eruptions by Cameroonian researchers." In addition, the project's effectiveness and impact have been moderately low; this is reflected in the absence of significant results of the researchers' efforts to disseminate the project's gas disaster research results to the local population. Although delays in the disbursement of counterpart funds and equipment provision affected the achievement of some outputs, the project period and costs on the Japanese side were within the plan. Therefore, efficiency of the project is high. Although slight technical issues have emerged in the current operation and maintenance of the equipment, there are good prospects for improvement/resolution, the equipment which is currently out of service will be utilized and the monitoring of the lakes and sample analysis are expected to resume through the follow-up cooperation consisting of equipment procurement and dispatching engineers for the lake degassing system and lake water monitoring scheduled in FY2022. Therefore, sustainability

of the project effects is high.

In light of the above, this project is evaluated as satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Implementing Agency

(1) Formulation of Specific Plan for Social Implementation and its Implementation

IRGM is responsible for surveying, researching, and providing information from a scientific point of view regarding disaster management under the jurisdiction of DPC. Since the personnel change at DPC, no major cooperation has been observed, and information based on scientific evidence on the mechanism of volcanic lake gas emission and measures to take in case of gas disasters, which is one of the outcomes of the project, has not been disseminated. IRGM should have an opportunity to communicate with DPC at an early stage, and when the lake degassing system and lake water monitoring are restored in Lake Monoun through the follow-up cooperation scheduled in FY2022, it should regularly inform DPC of the status of the lake and distribute the remaining copies of the leaflet through DPC, etc.

(2) Strengthening Systematic Storage of Water and Rock Samples

Although water and rock samples collected during the project were catalogued during the implementation and the samples were stored in the underground store of the laboratory, IRGM was not yet able to manage systematic storage independently.

When the follow-up cooperation is implemented in FY2022, IRGM, together with Japanese researchers, should organize the water and rock samples that are currently left unorganized in the underground storage of the laboratory and it should fully learn the methods of classifying and managing samples. Then, it is desirable to document the person in charge, records, and management methods and to utilize the water and rock samples collected after thorough classification and management for future research.

4.2.2 Recommendations to JICA

(1) Follow-Up on Unachieved Matters

In the follow-up cooperation scheduled for FY2022, or as a separate scheme, it is desirable to follow up on the “systematic storage of water and rock samples” and “social implementation” that were confirmed to be insufficiently achieved in this ex-post evaluation. Specifically, with regard to “systematic storage of water and rock samples,” one idea is for Japanese experts to prepare a manual on systematic storage of samples together with IRGM researchers and technicians when the follow-up cooperation is implemented in FY2022, as well as to classify samples that have been left unclassified.

For social implementation, a feasible action plan could be formulated with IRGM and

DPC with Japanese experts at the time of implementing the follow-up cooperation, and then periodically monitored by JICA.

It would also be possible for the JICA Cameroon Office to monitor the progress of water and rock sample classification and management by visiting the laboratory. As for social implementation, the Cameroon Office can directly confirm the progress of social implementation to IRGM officials and exchange opinions with them, so that IRGM officials will be aware of external interest and progress in social implementation can be expected.

4.3 Lessons Learned

(1) Effective Efforts in the Implementation Phase to Achieve the Overall Goal in Technical Cooperation

This project, formed in 2010, was implemented in the initial stage of SATREPS, which began in 2008. Therefore, the concept of social implementation (i.e., ways to return the research results to society after the international joint research project was completed) may not have been well established among JICA officials, and Japanese researchers who focused on the research results did not seem to have made concrete plans for social implementation. There was no detailed implementation plan for social implementation at the beginning of the project. In addition, although social implementation efforts were included in the recommendations at the mid-term review, at the time of the terminal evaluation, there was no plan for social implementation other than the distribution of leaflets prepared by the project in the form of action plans for the two participants in the thematic training in Japan. Although plans to achieve the overall goal often materialize as a project progresses, it is important that the project team (implementing agency and experts) at least agree on the expected results and implementation methods as social implementation and the roles of related organizations by the middle of the project period. If possible, they should try the planned method once, before completing the project. This approach would enable social implementation, which is the overall goal of the SATREPS project, by relevant organizations in the partner country after the project is completed. For example, JICA and the project team should take advantage of various project opportunities, such as study meetings before the start of the project, kick-off meetings after the start of the project, and regularly held Joint Coordinating Committees, to discuss fully and have a common understanding of the achievement of the overall goal.

(2) Formulation of a Flexible Technical Training Plan for Equipment to Be Procured

If advanced equipment is included in the equipment to be procured, the period of technical training should be set longer from the beginning, and if the expected operation of the

equipment is not sufficiently established, then additional inputs should be made during the project period. It is desirable to review the inputs and activities flexibly while ascertaining the proficiency of the target persons.

5. Non-Score Criteria

5.1. Performance

5.1.1 Objective Perspective

None

Attachment 1: Achievement Status of Outputs

Output	Indicator	Status as of the Project Completion (March 2016)
Output 1 The mechanism of limnic eruption is understood.	Indicator 1-1: A scientific journal paper Indicator 1-2: Report for local people. Indicator 1-3: Information on Web site Complementary indicator 1-1: Appropriate records for proper use of observation and analytical equipment Complementary indicator 1-2: Appropriate use of IC	<Achieved> ・ Indicator 1-1: One scientific journal paper was published in 2015 and 1 paper was published in 2017.[22] ・ Indicator 1-2: In November 2013, workshops for local people were conducted at Wum and Kouoptamo. ・ Indicator 1-3: Information was published on two websites. ・ Complementary indicator 1-1: As per the goal that the date of equipment use, analyst, sample ID, and analysis fee were recorded in the notebook at the laboratory, these were recorded in the laboratory notebook. ・ Complementary indicator 1-2: IRGM researchers were able to use the IC without any problems, and there were no technical challenges.
Output 2 Deepen understanding of the CO2 supply process to Lake Nyos and Lake Monoun.	Indicator 2-1: A scientific journal paper Indicator 2-2: Report for local people Indicator 2-3: Information on Web site Complementary indicator 2-1: Appropriate use of 13C Analyzer	<Partially unachieved> ・ Indicator 2-1: One scientific journal paper is published in 2015 (same as Output 1)[23], two papers was published in 2017.[24] ・ Indicator 2-2: Same as Output 1. ・ Indicator 2-3: Same as Output 1 ・ Complementary indicator 2: Not used (except for training) due to delay in provision of equipment and lack of gas samples.
Output 3 Deepen understanding of hydrogeological characteristics around Lake Nyos and Lake Monoun.	Indicator 3-1: A scientific journal paper Indicator 3-2: Report for local people	<Achieved> ・ Indicator 3-1: Three scientific journal papers were published, one of which was published by *Scientific Report,* which belongs to Nature Publishing Group.[25] ・ Indicator 3-2: Same as indicator 1-2 under Output 1.
Output 4 Better understanding of water-rock interactions in the CO2 supply system.	Indicator 4-1: A scientific journal paper Complementary indicator 4-1: Appropriate use of AAS and Picarro	<Indicator 4-1 was achieved, complementary indicator 4-1 achieved limitedly> ・ Indicator 4-1: One scientific journal paper was published in 2015. ・ Complementary indicator 4-1: AAS was installed in December 2013, two and a half years after the project started. At that time, operation training from manufacturer technicians was provided. From October 19 to November 16, 2014, a special researcher at Tokai University gave intensive training to IRGM technicians on how to use it. Furthermore, an IRGM researcher staying in

[22] Source: Terminal evaluation report p.7 and documents provided by JICA
[23] Source: Terminal evaluation report, p.8
[24] Source: Documents provided by JICA
[25] Source: Terminal evaluation report p.9 and documents provided by JICA

		Japan as a long-term trainee at Tokai University learned how to handle AAS at a Japanese manufacturer. ・ In 2015, the voltage fluctuated due to a lightning strike and it broke down, making it unusable for six months. At the terminal evaluation in November 2015, the counterparts answered that they were somewhat concerned about using the system. ・ Picarro was operated without any problems from the start of the project, but there was a period of at least two years when it was out of service due to problems with the electrical system and maintenance.
Output 5 Lakes Nyos and Monoun are monitored.	Indicator 5-1: A scientific journal paper	<Achievement is limited> ・ One scientific journal paper was published in 2015 (same as the paper for Output 1). ・ Although the indicator was achieved, no meteorological observation data has been collected since May 2014 when the cables of the meteorological observation station were cut by local people. The achievement of "establishment of a monitoring system" is limited.
Output 6 The experimental system for removing CO2-rich deep water to prevent gas rebuilding at Lake Monoun is set up.	Indicator 6-1: A technical paper on the CO2 removal system	<Achieved> ・ A solar powered deep water removal system was installed in Lake Monoun, and the possibility of forced CO2 degassing was investigated. ・ Indicator 6-1: One technical paper was published in 2010.[26]
Output 7 Magmatism of Oku volcanic zone is understood.	Indicator 7-1: Ph.D. thesis Indicator 7-2: A scientific journal paper	<Nearly achieved> ・ Geochemistry of maar-bearing volcanoes has been investigated in the Oku Volcanic Group along the Cameroon Volcanic Line (CVL). The activity "Geological maps of the Nyos and Monoun areas are produced" was changed to "Eruptive history of Nyos volcano is understood" due to lack of disbursement of the counterpart fund. ・ Indicator 7-1: One Ph.D. thesis was published in 2014[27] and one in 2015[28]. ・ Indicator 7-2: Two scientific journal papers were published; one in 2014[29] and one in 2015[30]. Two more to be submitted by the end of the project.

[26] Source: Terminal evaluation report, p.11
[27] Source: Terminal evaluation report, p.12
[28] Source: Terminal evaluation report, p.12
[29] Source: Terminal evaluation report, p.12
[30] Source: Terminal evaluation report, p.12

Output 8 Geochemical parameters of lakes along CVL other than Nyos and Monoun are understood.	Indicator 8-1: A scientific journal paper	<Achieved> ・ Indicator 8-1: Two scientific journal papers were published in 2014.[31]
Output 9 The results of scientific monitoring are systematically share with DPC.	Indicator 9-1: Seminar with DPC Indicator 9-2: Special session in the 9th workshop of the Commission on Volcanic Lakes (CVL-9)	<Achieved> • Indicator 9-1: Staff of IRGM and DPC participated in the "community based disaster risk management" thematic training organized by JICA in Kobe, Japan in July 2015. They jointly prepared an action plan which included a workshop for local people. As part of the implementation of this action plan, a workshop was held for local people in February 2016. • Indicator 9-2: IRGM hosted the CVL-9 in Yaoundé, Cameroon in March 2016. The conference provided an opportunity to disseminate the results of the project to the world.

[31] Source: Terminal evaluation report, A5-1