水銀使用を中止したモンゴル国の人力小規模採掘地における環境監査

村尾 智[1]、後藤祥子[2]、Jambardorj Uramgaa[3]、Baatar Tumenbayar[3]

Sainbileg Minjin[4]、世良耕一郎[5]

[1]産業技術総合研究所地質調査情報センター
305-8567　茨城県つくば市東 1-1-1

[2]日本アイソトープ協会仁科記念サイクロトロンセンター
020-0603 岩手県滝沢市留が森 348-58

[3]Sans Frontiere Progres, Ulaanbaatar, Mongolia

[4] MICHIKO Foreign Language Training and Translation Center
Ulaanbaatar, Mongolia

[5]岩手医科大学サイクロトロンセンター
020-0603 岩手県滝沢市留が森 348-58

要旨

モンゴル国の人力小規模金採掘においては長らく水銀が使用され環境汚染を引き起こしてきた。しかし、近年、環境保護や労働安全の遵守を行えば国際価格で金の買取を保証する「エシカルジュエリー」の概念が導入されたことにより、水銀を使用しない稼行をアピールするグループが出現している。しかし、実際に、水銀使用を中止したかどうかを、現場の視察だけで判断する事は困難である。このため、エシカルジュエリーの実務では、環境監査手法の確立が重要な課題となる。そこで、筆者らは、現場と周辺で環境試料を採集し、NMCC の PIXE を用いて、有害元素農集の程度を調査した。使用した装置は、非破壊で多元素同時分析が行える上、試料調製が簡単で、信号の定量化も短時間ですむ特徴を有しており、調査を極めて短時間で済ませることができた。PIXE 法はエシカルジュエリーの環境監査ツールとして極めて有効である。

Environmental audit of mercury-free operation at artisanal/small-scale mining sites in Mongolia

Satoshi Murao[1], Shoko Goto[2], Jambardorj Uramgaa[3], Baatar Tumenbayar[3], Sainbileg Minjin[4] and Koichiro Sera[5]

[1]National Institute of Advanced Industrial Science and Technology
1-1-1 Higashi, Tsukuba 305-8567, Japan

[2]Nishina Memorial Cyclotron Center, Japan Radioisotope Association
348-58 Tomegamori, Takizawa, Iwate 020-0603, Japan

[3]Sans Frontiere Progres
P.O.Box 46, Ulaanbaatar – 46, Mongolia

[4]MICHIKO Foreign Language Training and Translation Center
Ulaanbaatar, Mongolia

[5]Iwate Medical University Cyclotron Research Center
348-58 Tomegamori, Takizawa, Iwate 020-0603, Japan

1 Introduction

In spite of the strict environment policy, mercury contamination is still present in various environmental media and food (especially fish) all over the globe. One of the reason for such contamination is the artisanal/small-scale gold mining (ASGM) where informal gold-ore beneficiation releases mercury due to the amalgamation. According to UNEP[1)], mercury release from ASGM is estimated to be about 1,400 t/year making it the largest global demand sector for mercury.

In order to mitigate the use of mercury in the ASGM sector, “ethical jewelry” is recently promoted as an economic incentive to the miners[2)]. The ethical jewelry requires responsible conducts to all of the stakeholders in the supply chain and secures fair payment to the players. Some mining groups began to follow this idea and announced that they do not use mercury any more[3)].

PIXE at NMCC is, because of the physical features, highly expected to be an ideal tool for the environmental audit to confirm the right conducts at ASGM operations, and thus the authors harnessed the system to verify that a group in Mongolia who assert mercury-free work is obeying the standards and rules.

2 ASGM in Mongolia

In gold producing regions in Mongolia always seen are artisanal/small-scale miners who dig the ground or pan the river sediment (Figs. 1 and 2). They are called *Ninja* after Japanese cartoon *Ninja*

Turtles because they carry plastic water basin on their back like turtle's shell. Such informal mining started around 2000 [4] and is now rampant all over the nation[5].

Fig. 1 An artisanal underground mining site in Mongolia where they follow ecological gold rules.

Fig. 2 An example of artisanal placer gold mining in Mongolia. Some workers are female.

Recently some miners who learnt eco-friendly way of small-scale mining started to introduce mercury-free technology and disseminate it to other groups. They invite Ninjas who use mercury to consider the environment and human rights and to join their NGO which designates *Artisanal and Small Scale Mining National Federation of Mongolia.* This is a big umbrella which holds many ASGM groups like SAM Project group in this study.

Fig. 3 Office of Artisanal and Small Scale Mining National Federation of Mongolia in Ulaanbaatar

Fig. 4 An example of mercury-free ore dressing plant which was set up by Swiss ODA.

The SAM group is a miners' organization[3] which was initially assisted by Swiss Agency for Development and Cooperation (SDC) through its *Sustainable Artisanal Mining (SAM)* project[6] to get information and mercury-free ore dressing plants (Figs. 3 and 4). They assert that they do not use any toxic chemicals except for small amount of acid to dissolve impurities in gold concentrate.

3 Samples

Environmental samples were obtained in and around the ASGM site in Bayanhongor Aimag

and from an ore dressing plant in Mandal community, Zuunkharaa Soum, Selenge Aimag. In Bayanhongor, a SAM project site was visited and workers' hairs were taken after getting their informed consent. Also Nariniiguur community of Bayan-Ovoo Soum near the SAM site was visited and local people's hairs were obtained after getting informed consent (Appendices I and II). Foodstuff in a Mongolian-style meat soup was also sampled. At Mandal plant (Fig. 4), tailings were taken after getting permission from the person in charge of the plant.

4 Analysis

Food stuff was dried and ground in an agate mortar till mixture is a fine powder. A slight portion of the powder was taken and put on the 4.0 μm polypropylene film and was fixed with 3 μl of 1.0 % collodion solution as a tiny patch.

The targets were bombarded with a 2.9 MeV proton beam extracted from a small-sized cyclotron at NMCC, and the emitted X-rays were simultaneously measured with two Si(Li) detectors. X-ray absorbers were used for the No. 1 detector. 500-μm-thick Mylar film was used for the food, while 300-μm Mylar was used for the hair samples.

As is shown on Table 1 foodstuff showed no contamination of heavy metals. All of the human hairs indicated no mercury anomaly but higher concentration of arsenic and lead. In the tailings mercury was below the detection limit.

5 Concluding remarks

Influence of the toxic elements seems to be minimal in around the ASGM who asserts the compliance of laws and regulations. Because of the following features, PIXE at NMCC is regarded to be a robust instrument to assist the environmental monitoring and audit of the ethical jewelry.

- ✓ Capability to analyze any type/form of specimen
- ✓ Simultaneous measurement of many elements heavier than sodium. Almost equal sensitivity for most elements.
- ✓ Nondestructive analysis
- ✓ Analysis of untreated specimens
- ✓ Short measurement time typically less than five minutes for one specimen

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Code	MG0910-1	MG0910-3	MG0910-2
Run #	20373&20381	20374&20382	20375&20383
Sample	Sheep meat	White needle	Onion
Na	62	57	7286
	8.4	5.3	249
Mg	14	5.4	1435
	5.2	3	74
Si	9.2	4.6	ND
	3.8	2.3	
P	120	68	8341
	6.4	3.6	265
S	406	92	2725
	17	5.1	124
Cl	312	595	36836
	13	20	1133
K	117	225	14740
	5.5	8.2	458
Ca	30	33	4623
	3.1	2.1	152
Ti	1.6	ND	ND
	0.5		
Fe	7.8	2.4	113
	0.6	0.2	4.1
Cu	0.3	0.5	21
	0.07	0.1	1.2
Zn	16	1.3	94
	1.2	0.1	3.3
Br	0.9	1.3	61
	0.2	0.1	2.8
Sr	ND	0.6	127
		0.1	5.6

Table 1 PIXE analysis of food from Nariniiguur community, Bayan Obbo Soum*, Bayanhongor Aimag**, Mongolia Values in ppm, values in lower row indicate one sigma of the analysis. ND: not detected.

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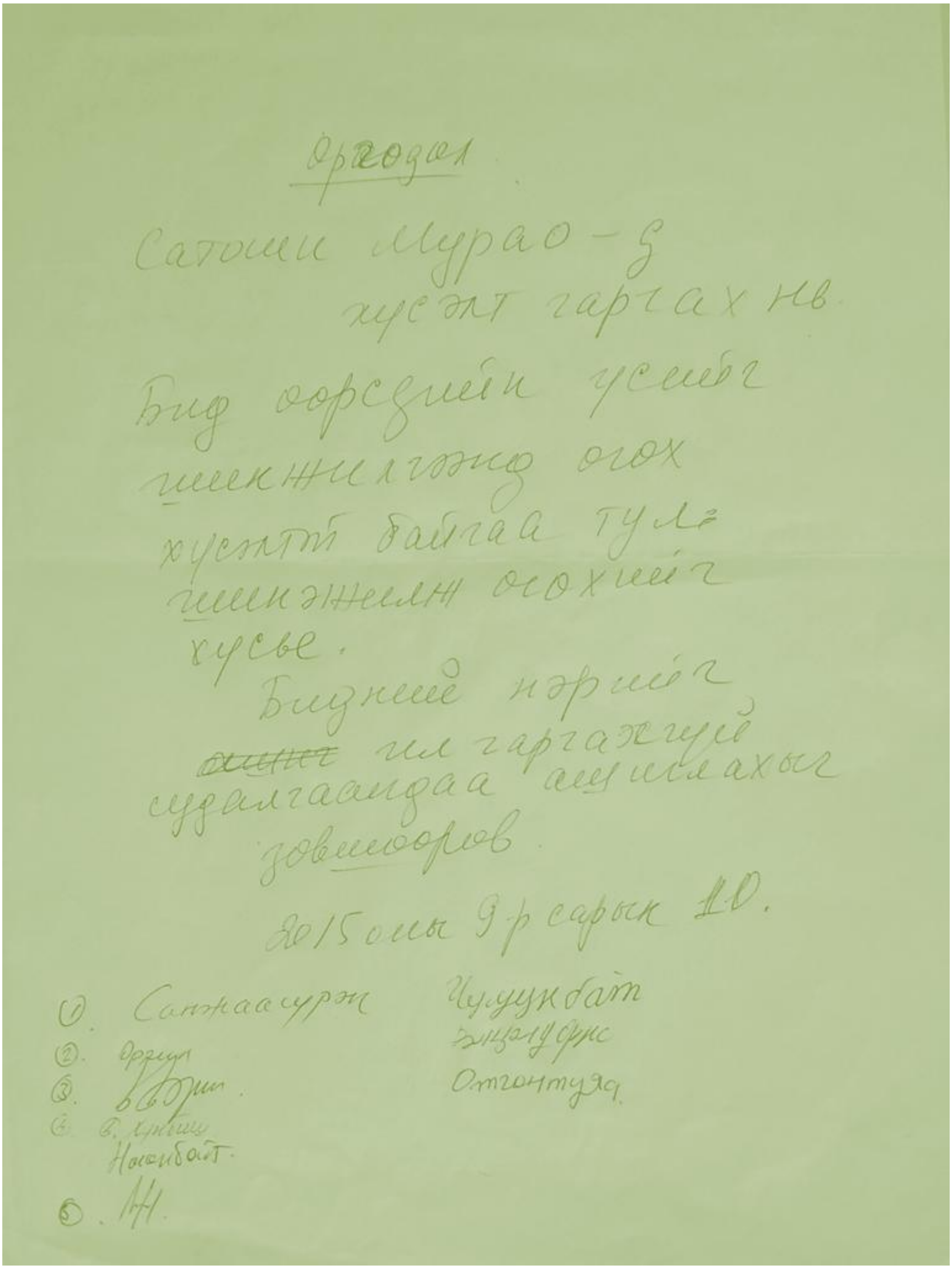
* A soum (Mongolian: сум) is the second level administrative subdivision below the aimags (provinces) in Mongolia.

** An aimag (аймаг) is an administrative subdivision in Mongolia, roughly comparable to Japan's prefecture. Mongolia is divided into 21 Aimags except for the capital Ulaanbaatar.

APPENDIX I



Өргөдөл

Сатоши Мурао-д
хүсэлт гаргах нь.

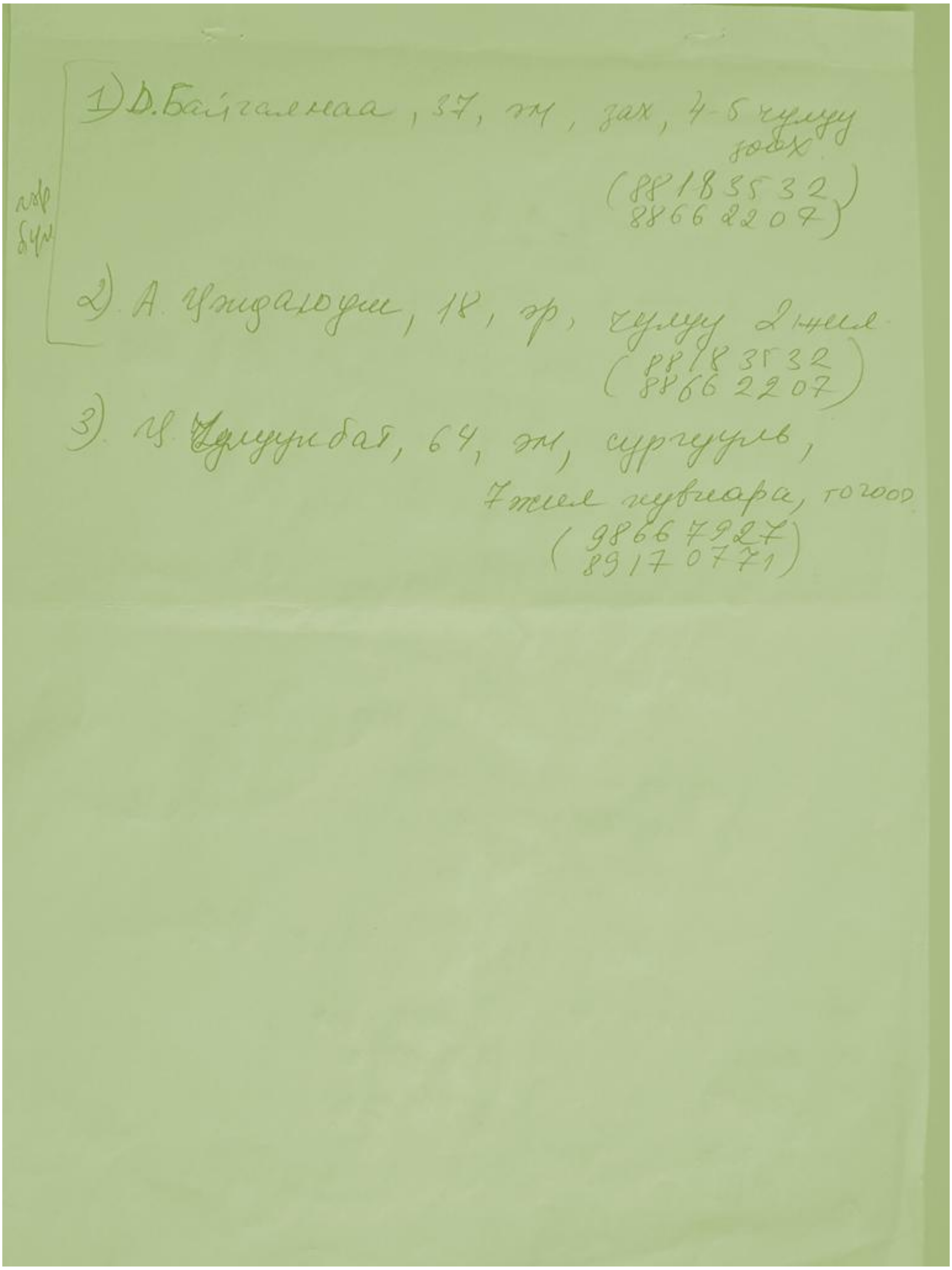
Бид өөрсдийн үсийг
шинжилгээнд өгөх
хүсэлтэй байгаа тул
шинжилгээнд өгөхийг
хүсье.

Бизнесийн нэрийг
~~[illegible]~~ ил гаргахгүй
судалгаандаа ашиглахыг
зөвшөөрөв.

2015 оны 9-р сарын 10.

1. Санжаасүрэн Чулуунбат
2. [illegible] [illegible]
3. [illegible] Отгонтуяа.
4. [illegible] [illegible]
5. [illegible]

APPENDIX II



1) Д.Байгалмаа, 37, эм, зах, 4-5 чулуу зоох
(88183532
88662207)

2) А. Ужидалодш, 18, эр, чулуу 2 жил
(88183532
88662207)

3) Ц. Чулуунбат, 64, эм, сургууль,
7 жил хувиара, тогоод
(98667927
89170771)