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Stakeholders Platform Meeting (Zoom)

'Improving Environmental Management in the Mining Sector of Suriname with Emphasis on Artisanal and Small- Scale Goldmining' (EMSAGS) - Project

Date: 20 oktober 2022

Time: 09:00 a.m. – 13:15 p.m.

Location: Banquet hall Torarica

Participants

The SP meeting was attended by representatives of:

- Ministries,
- Indigenous and Tribal peoples,
- Private sector,
- Small and large-scale mining organizations,
- NGOs, and
- Anton de Kom University.

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Agenda

AGENDA	
9:00 – 9:30 a.m.	Registration
9:30 – 9:40 a.m.	Welcome
9:40 – 9:50 a.m.	Opening by Acting General Directeur NIMOS, Mr. Cedric Nelom
9:50 – 10:30 a.m.	Presentation dissertation: *"The influence of prenatal exposure to non-chemical and chemical stressors on birth outcomes in Suriname"* By: Dr. Anisma Gokoel
10:30 – 11:15 a.m.	Presentation: *"Rosebel Goldmines NV management of Small Scale Mining"* By: MSc. in Mineral Geoscience, Ms. Marijke Agwense of IAMGOLD/ Rosebel Gold Mines
11:15 a.m. – 12:00 p.m.	Presentation: *"Mercury background values in soils and saprolites in the gold-rich greenstone belt of Suriname, Guiana Shield: The role of parent rock and residual enrichment"* By: Prof. Salomon Kroonenberg
12:00 – 12:15 p.m.	Recap and Next meeting- EMSAGS PMU. Closing by the Permanent Secretary of Mining, Ministry of Natural Resources, Ms. P. Simons
12:15 – 13:15 p.m.	Lunch

Welcome and Opening

The Stakeholder Engagement Specialist, Ms. C. Elliott- Banai, welcomes the participants at 10:00 and informs that due to unforeseen circumstances, the Director of NIMOS is unable to open the meeting.

Presentation 1: "The influence of prenatal exposure to non-chemical and chemical stressors on birth outcomes in Suriname"

In this presentation Dr. Anisma Gokoel discusses the prenatal exposure to non-chemical and chemical stressors in pregnant women.

See annex 1 for the presentation.

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No.	Questions / Comments	Answers
1.	**Artisanal Gold Council – Marieke Heemskerk**: a. Is it possible for a pregnant woman in Suriname to get tested for mercury levels in the blood? b. Does the Medical Mission carry out proactive testing in high risk groups?	**Anisma Gokoel:** a. Not sure if the Central Lab can test for mercury levels in blood. Mercury levels in the hair can be tested at the National Zoological Collection Suriname (NZCS). For this research into mercury concentrations in the blood, blood samples were sent to a laboratory abroad. b. Not sure if this is already being done by the Medical Mission.
2.	**Chantal Landburg:** Did you notice anything about the Apgar score of the children whose mothers had high levels of mercury?	**Anisma Gokoel:** No direct relationship has been identified. The absolute number with a low Apgar score was 15. Most children had a good Apgar score. The number was also much too small to see an association. We did see that there was an association with early birth.
3.	**Camp Mining – Melleo Naana:** In the city there are many gold buying companies that buy and process gold almost every day. My conclusion is that the pollution in Paramaribo will be much greater because gold is not processed every day in the interior. Where do you make the connection between the result of your research in the interior and the many gold buying companies in the city.	**Anisma Gokoel:** During the research, various regions such as Paramaribo and the surrounding area, Nickerie and the Interior were also examined. No significance was found, so no statement can be made about where it occurs most often. The high mercury levels mainly occurred among the indigenous and tribal peoples. I agree with you that gold is processed daily in Paramaribo, which also pollutes our atmosphere. It could be that the

		pollution is more than the Interior, but more research is needed for that.
4.	**Anton de Kom University – Rene Artist:** In your presentation you noted that a mental discomfort has been observed mainly among some of the female inhabitants of the interior. What is meant by mental discomfort, why especially in that group and what is the cause?	**Anisma Gokoel:** The results you mention were found in the study by Gunther et. al. What I conclude from this is that psychological discomfort was tested by means of a questionnaire and that depressive symptoms occurred. We looked at which socio-demographic variables are associated with psychological discomfort. This showed that the interior residents had a higher chance of experiencing psychological discomfort. This research was not only conducted in the interior, but a sample was drawn from the whole of Suriname.
5.	**Artisanal Gold Council – Marieke Heemskerk**: On the one hand you have that higher mercury levels lead to negative birth outcomes and on the other hand stress can also lead to negative birth outcomes. It could be that people in the interior experience more stress and that they have both more stress and higher mercury levels. Did you check for stress when you did the mercury analysis?	**Anisma Gokoel:** A model with stress, mercury and other socio-demographic factors such as income was used during the research.
6.	**Camp Mining – Melleo Naana:** The greatest mercury pollution in Suriname was before the creation of the Brokopondo reservoir. As young people from Nieuw Koffiekamp, we used to go looking for mercury along the railway line to sell for the gold diggers. Mercury pollution is not something from now, but from years ago. It must also be investigated why there was so much mercury in Suriname before the creation of the reservoir sixty years ago.	

7.	**Alliance for Responsible Mining – Johannes Abielie:** a. We also did a baseline study of mercury occurrences in the physical environment as well as in humans and we measured generally low levels in people in the Brokopondo district. The French research institute IRD took samples and what we can conclude from the results is that mercury accumulated in the food chain is more easily found in people's bodies. You hardly see any mercury in the body of the person who works with mercury, but mercury can be traced in the person who eats food that is contaminated with mercury. In that case the health impact is greater. In one of the villages, ten of the twelve samples had an elevated mercury contamination, a few of which had eight to nine times the acceptable value. Those people are not that closely involved in small-scale gold mining, but if you look at their dietary habits, they do have an association with the Brokopondo reservoir. b. The largest source of mercury contamination in Suriname was the chimney of Alcoa's smelter. All the gold that is mined in Suriname is processed in a small part of Paramaribo North, so you can imagine how concentrated the contamination of mercury in the air is in Paramaribo North.	
8.	**Arioene Vreedzaam** I'm also doing a mercury study looking more at the environment. We may be coming out this year with publications on mercury measurements in the hair of women, mercury in fish, water and river sediment. We found very high levels of mercury in Apoera, Sipaliwini and Kwamalasemutu, Palumeu and Apetina.	

9.	**NIMOS - Donovan Bogor:** We also planned to go deeper into the possible mercury depositions in Suriname where we wanted to determine the age of mercury and establish if it is Surinamese mercury or mercury from abroad. Hopefully we will get the funding available to carry out this research.	

Presentation 2: "Rosebel Gold Mines NV management of Small Scale Mining"

In this presentation, Rosebel Gold Mines' representative, Mrs. Marijke Agwense, gives an overview of the various initiatives that have been carried out by Rosebel Gold Mines in the surrounding areas of the Rosebel concessions where the small-scale miners are active. For more information on the presentation please contact Mrs. Agwense (see info in the registration list).

No.	Questions / Comments	Answers
1.	**Anton de Kom University – Rene Artist:** Have you noticed a correlation between the movement of small scale miners' activities on the concessions and the gold price?	**Marijke Agwense:** The gold price has something to do with it, but it's not that significant. It's only one of the aspects.
2.	**Chantal Landburg:** You indicated that finances are a problem. Can you explain that in more detail.	**Mary Agwense:** Mercury free mining is still trial and error and you need to have the funds available to keep investing in new methods. The budget of the Community Relations department is often informed by activities we do in the communities. With small scale mining it is more social risk management and there isn't a large budget available for this.

3.	**Artisanal Gold Mining – Marieke Heemskerk:** We have heard in the media that Rosebel Gold Mines has been sold to Zijin Mining Group. The experience with mines owned by Chinese mining companies in various African countries is that the health and safety standards, but also the community relations standards, are significantly different from those of a Canadian company. What will the acquisition mean for the community relations plans you have for the future.	**Yoanne Najoe:** At the moment we do not know more than what has been reported in the media. I think we should embrace the change and see what it brings us.
4.	**Camp Mining – Melleo Naana:** As Camp Mining we would like to express a special word of thanks to Rosebel Gold Mines for the experience gained in recent months. Can you share this working method with Newmont so that they can also implement what has been done in Nieuw Koffiekamp in Marowijne.	**Yoanne Najoe:** For every organization it is about finding out what works best for them given their situation and operation. We are willing to enter into partnerships with our peers if the need arises. It will mainly depend on their own situation, challenges and if they see value in our working method.

Presentation 3: "Mercury background values in soils and saprolites in the gold-rich greenstone belt of Suriname, Guiana Shield: The role of parent rock and residual enrichment"

In this presentation, Prof. Kroonenberg, explains the results of an assessment of mercury levels within gold bearing geological formations of Suriname.
See annex 2 for the presentation.

No.	Questions	Answers
1.	**Alliance for Responsible Mining - Yves Bertrand:** Despite of the low levels of mercury that you found on artisanal and small scale mining sites, do you think that remobilizing the saprolites with milling and processing will also remobilize the mercury and have an influence on the mercury levels in the streams?	**Salomon Kroonenberg:** What we see in the streams could be largely materials from the saprolites and top soil. Even though we see increasing mercury levels in the younger sediments, it can be the result of recent mining and not necessarily the result of mercury pollution. You also see it in the quality of the sediment if you look at the unpolluted rivers than the sediment is grey but if you look at the rivers that have material that comes from the mines, the sediment is red.
2.	**Alliance for Responsible Mining - Johannes Abielie:** In the baseline that we did we found high levels of mercury concentration in people that consume fish from the Brokopondo reservoir. Why do you think that there is such a high concentration of mercury in the Brokopondo lake?	**Salomon Kroonenberg:** The material in the creeks come from the mountains and rocks so there is reason to believe that you wont find the same results from the mountains in the creeks.

3.	**NIMOS - Donovan Bogor:** Professor Kroonenberg's research is part of a three-part study. An important part that is now performed by Mrs. Wesenhagen in collaboration with Mr. Wip has to do with the air pollution in Paramaribo. The research is still ongoing and hopefully we will receive the results very soon.	

Next meeting

The EMSAGS Project Management Unit proposes to have the next meeting in February 2023. A report of the current meeting, including the presentations, will be shared with the members of the Stakeholders Platform and on the EMSAGS website.

Closing

In her closing remarks, the Permanent Secretary of the Ministry of Natural Resources, Mrs. P. Simons, thanks the attendees and presenters for their attendance. The Ministry of Natural Resources is well aware of the mercury use in Suriname and is pleased with the various studies that are currently being done in the context of mercury pollution. Suriname has committed itself to the Minamata Convention and the EMSAGS project is one of the ways in which we want to give substance to this. The use of mercury occurs all over the world and foreign countries are much further than Suriname when it comes to implementing environmentally responsible techniques. Finding environmentally responsible techniques does not happen overnight. Together with the small scale miners, we want to see which method we can identify and thus limit the use of mercury in Suriname.

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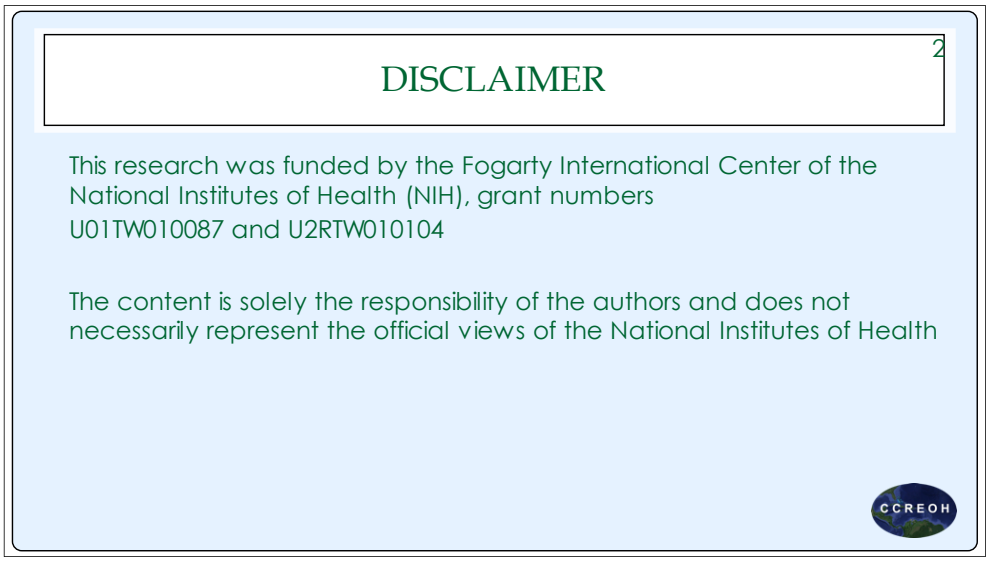
Annex 1

Presentation 1: "The influence of prenatal exposure to non-chemical and chemical stressors on birth outcomes in Suriname"



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OVERVIEW

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- Background and significance
- Research goal
- Hypothesis and aims
- Results
- Discussion
- Recommendations

BACKGROUND

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- The prevalence of preterm birth (PTB) and low birthweight (LBW) in Suriname: respectively 14% and 15% (2016-2017) (Verschueren et al. 2020)
- Pregnant women may be exposed to multiple environmental factors at once: non-chemical and chemical stressors (Pao at al. 2019; Vesterinen 2017)
- Suriname: (1) Use of mercury (Hg) in goldmining (ASGM), (2) High levels of Hg in hair (above USEPA action level) in women and children living in the Interior (3) 19.5% mental distress, particularly in (among others) participants of Tribal descent and living in urban areas, (Ouboter et al. 2012), (Ouboter et al. 2018; Mohan et al. 2005), (Gunther et al. 2017)
- No studies have been conducted to examine the influence of non-chemical and chemical exposures on birth outcomes in Suriname

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RESEARCH GOAL

Examine the influence of prenatal exposure to **non-chemical** and **chemical stressors** in pregnant women **on birth outcomes**

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HYPOTHESIS

Prenatal exposure to **non-chemical** and **chemical stressors** in pregnant women **negatively** influences **birth outcomes**

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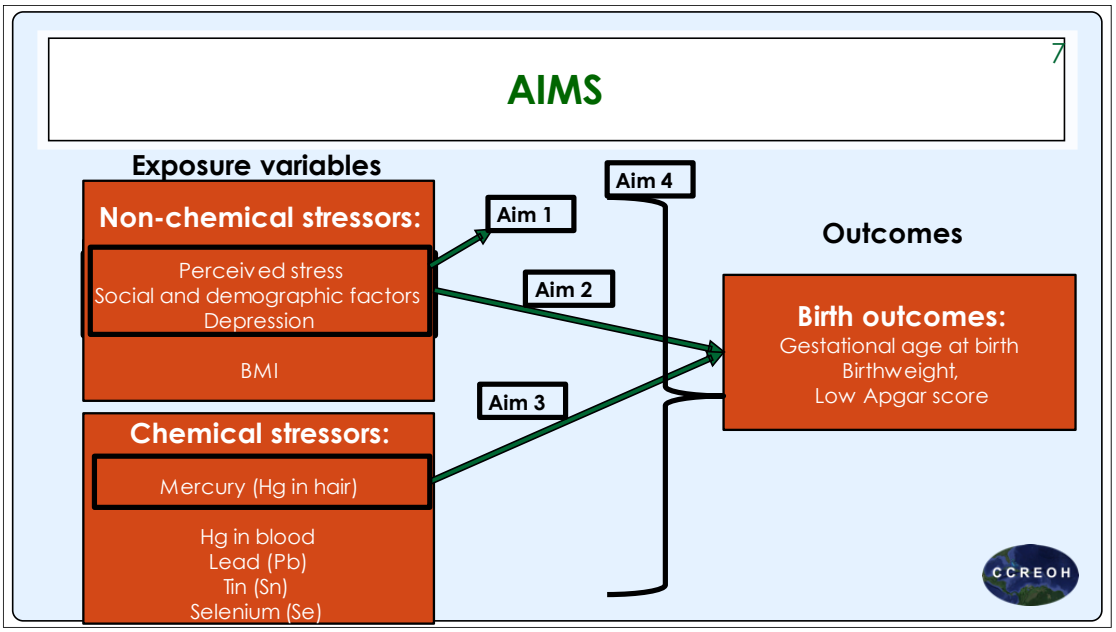

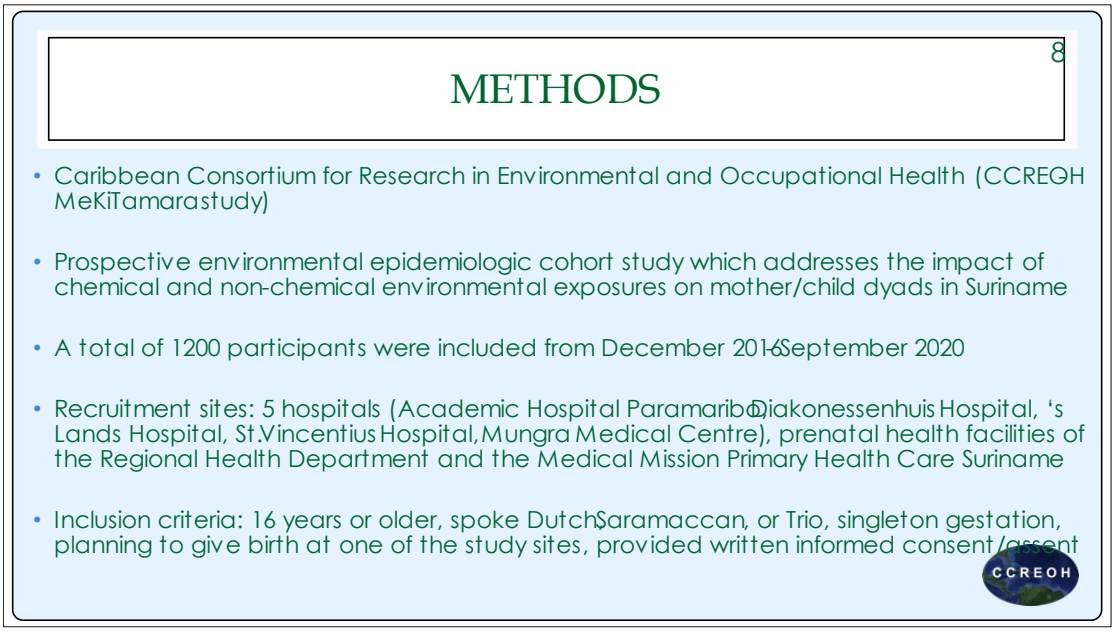

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CARIBBEAN CONSORTIUM FOR RESEARCH IN ENVIRONMENTAL AND OCCUPATIONAL HEALTH (CCREOH)
RECRUITMENT SITES & NUMBERS (N=1200)

Demographics study population:

- ***Region***:
Paramaribo: 768
Nickerie:224
Interior: 208

- ***Age***: 16-49 years

- ***Ethnicity***:
Creole: 21.8 %
Hindustani: 19.7%
Indigenous: 10.8%
Javanese:7.1%
Maroon:21.9%
Mixed:18.6%

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Maternal Assessments Timeline

Assessments	Trimester		Birth	12 mos	36 mos
	1st/2nd	3rd			
Mother					
Obstetric history	•	•			
Demographics	•				
Residency	•	•			
Anthropometrics	•	•			
Marital status	•				
Ethnicity	•				
Occupation	•				
Education	•				
Household income	•				
Household composition	•				
Maternity care	•	•			
Medication		•			
Questionnaires					
SF 36 Health Survey	•	•			
Social Support List	•				
Brief Trauma Interview	•	•			•
Cohen's Perceived Stress Scale	•	•			•
Edinburgh Depression Scale	•	•			•
ASSIST V3.0	•	•			•
Exposure History	•				
Prenatal Life Events Scale	•	•			
Subjective Social Status	•	•			
Dietary Assessment	•	•			
Family Environment Scale					•
Parenting Stress Index					•
Biological samples					
Hair	•				
Blood	•	•			
Urine	•	•			
Buccal swab	•				

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Children's Assessments Timeline

Assessments	Trimester	Birth	12 mos	36 mos
At birth				
Mode of delivery		•		
Cord or heelprick blood sample		•		
Birth outcomes		•		
Child development				
Physical examination			•	•
Questionnaires				
Generation R			•	•
M-CHAT				•
Child Behavior Checklist				•
Bayley SEQ				•
Ages and Stages Questionnaire				•
Neurodevelopmental tests				
BSID-III			•	
CANTAB				
Biological samples				
Buccal swab			•	•
Blood				•
Urine				•

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AIM1: CHARACTERIZE THE INFLUENCE OF PERCEIVED STRESS, SOCIAL- AND DEMOGRAPHIC VARIABLES ON DEPRESSION DURING PREGNANCY; **METHODS**

- 1st or 2nd trimester: data of 1143 participants
- 3rd trimester: data of 743 participants

- Questionnaires: three self-report questionnaires

1. Social Support List-Interactions-12 (SSL-I-12)

- SSL-I-12 assesses social support (support, affection, and attention from family and friends)
- median scores used as cutoff points (higher scores=>high social support)

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AIM1: CHARACTERIZE THE INFLUENCE OF PERCEIVED STRESS, SOCIAL- AND DEMOGRAPHIC VARIABLES ON DEPRESSION DURING PREGNANCY; **METHODS CONT'D**

2. Cohen's Perceived Stress Scale (PSS)

- PSS assesses perceived stress (e.g. the degree of experiencing stress due to having no control over things)
- total score ranges from 0 (lowest stress level) to 40 (highest stress level) points; cut-off of ≥ 20 points for high perceived stress (75th percentile)

3. Edinburgh Postnatal Depression Scale (EPDS)

- assesses postnatal depression, but has been validated for use prenatally (EDS) (anxiety and depression symptoms)
- sum score of all statements: 0 to 30 points (higher score means higher risk on probable depression); cut-off point of ≥12 points for probable depression

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AIM1: CHARACTERIZE THE INFLUENCE OF PERCEIVED STRESS, SOCIAL- AND DEMOGRAPHIC VARIABLES ON DEPRESSION DURING PREGNANCY

- Probable depression during the 1st/2nd and 3rd trimester: respectively **22.4%** and **17.6%** (Gokoel et al. 2021)
- **Throughout pregnancy, almost half of the pregnant women** with high perceived stress levels had probable depression (Gokoel et al. 2021)

Variables	1st/2nd trimester		3rd trimester	
	AOR (95 % CI)	p-value	AOR (95% CI)	p-value
Social Support				
Individual resilience	1.45 [1.04-2.01]	0.027	1.65 [1.03-2.63]	0.038
Low	1		1	
High				
Perceived stress (1st/2nd trimester)	1		1	
Low	7.21 [5.15-10.09]	0.001	1.92 [1.18-3.11]	0.008
High				
Perceived stress (3rd trimester)				
Low	-	-	1	0.001
High			7.48 [4.64-12.05]	
Educational level				
None, primary, lower secondary/vocational	1.72 [1.16-2.55]	0.007	2.23 [1.29-3.86]	0.004
Upper secondary/vocational or tertiary	1		1	

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MANUSCRIPT 1

16

Gokoel *et al. Reprod Health* (2021) 18:136
https://doi.org/10.1186/s12978-021-01184-x

Reproductive Health

RESEARCH Open Access

Influence of perceived stress on prenatal depression in Surinamese women enrolled in the CCREOH study

Anisma R. Gokoel[1,3*], Firoz Abdoel Wahid[1,2], Wilco C. W. R. Zijlmans[2,3,4], Arti Shankar[2], Ashna D. Hindori-Mohangoo[2,4], Hannah H. Covert[2], Meerte-Sigrid MacDonald-Ottevanger[1,5], Maureen Y. Lichtveld[6] and Emily W. Harville[7]

Results

Aims 2 & 3:

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Assess the impact of prenatal exposure to **perceived stress** and **depression** on **birth outcomes** (PTB, LBW and low Apgar score)

&

Assess the impact of prenatal exposure to **mercury** on **birth outcomes** (PTB, LBW and low Apgar score)

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AIM 2&3: ASSESS THE IMPACT OF PRENATAL EXPOSURE TO PERCEIVED STRESS, DEPRESSION AND MERCURY ON BIRTH OUTCOMES; **METHODS**

- **Questionnaires**:
  - Cohen's Perceived Stress Scale (PSS) (cut-off point 75th percentile)
  - Edinburgh Depression Scale (EDS) (cut-off point ≥12 points)
- **Birth outcome variables:**
  - low birthweight: <2,500 g
  - preterm birth: before 37 completed weeks of gestation
  - low Apgar score: <7 at 5 min
- **Hair mercury**: cut-off elevated mercury levels: ≥1.1 µg/g, US Environmental Protection Agency (US EPA) action level

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AIM 2&3: ASSESS THE IMPACT OF PRENATAL EXPOSURE TO PERCEIVED STRESS, DEPRESSION AND MERCURY ON BIRTH OUTCOMES

- Prevalence of preterm birth (PTB), lowbirthweight (LBW) and low Apgar score were respectively: 15.2%, 13.2% and 3.3%(Gokoel et al. 2020)
- Perceived stress was associated with low Apgar score (OR 9.73; p=0.004) (Gokoel et al. 2020)
- Elevated hair mercury levels were significantly associated with preterm birth (OR 2.47; p=0.039) (Gokoel et al. 2020)

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AIM 2&3: ASSESS THE IMPACT OF PRENATAL EXPOSURE TO PERCEIVED STRESS, DEPRESSION AND MERCURY ON BIRTH OUTCOMES

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Variables	Birthweight AOR [95% CI]	p-Value
Age (Years)		**0.008**
16–19	0.44 [0.14-1.37]	
20–34	1	
35+	**3.15 [1.37–7.24]**	
Educational level		**0.020**
None, primary, lower secondary/vocational	**2.62 [1.11–6.18]**	
Upper secondary/vocational or tertiary	1	
Parity		**0.019**
0 (nulliparous)	**3.16 [1.29–7.73]**	
1	1.06 [0.39-2.87]	
≥2	1	

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MANUSCRIPT 2

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International Journal of Environmental Research and Public Health
MDPI

Article

Influence of Prenatal Exposure to Mercury, Perceived Stress, and Depression on Birth Outcomes in Suriname: Results from the MeKiTamara Study

Anisma R. Gokoel [1,2,*], Wilco C. W. R. Zijlmans [1,2,3], Hannah H. Covert [3,*], Firoz Abdoel Wahid [1,3], Arti Shankar [4], M. Sigrid MacDonald-Ottevanger [1,5], Ashna D. Hindori-Mohangoo [3,6], Jeffrey K. Wickliffe [3], Maureen Y. Lichtveld [3] and Emily W. Harville [7]

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Results

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Aim 4:

Examine the **cumulative exposure** to **non-chemical stressors** (perceived stress, depression, BMI) and **chemicals** (Hg, Pb, tin (Sn), Se) on **birth outcomes** (GA, BW, Apgar score)

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AIM 4: EXAMINE THE CUMULATIVE EXPOSURE TO NON-CHEMICAL STRESSORS AND CHEMICALS ON BIRTH OUTCOMES; **METHODS**

- 384 participants included
- Exposures:
  - Chemicals: (mercury (Hg), lead (Pb), selenium (Se), tin (Sn)
  - Perceived stress, probable depression, and social support
- Demographic variable: BMI
- Birth outcomes: gestational age at birth, birthweight and Apgar score

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AIM 4: EXAMINE THE CUMULATIVE EXPOSURE TO NON-CHEMICAL STRESSORS AND CHEMICALS ON BIRTH OUTCOMES; RESULTS: PATH MODEL OF RELATIONSHIPS AMONG NON-CHEMICAL STRESSORS, THE LATENT CHEMICAL CONSTRUCT, AND BIRTH OUTCOMES

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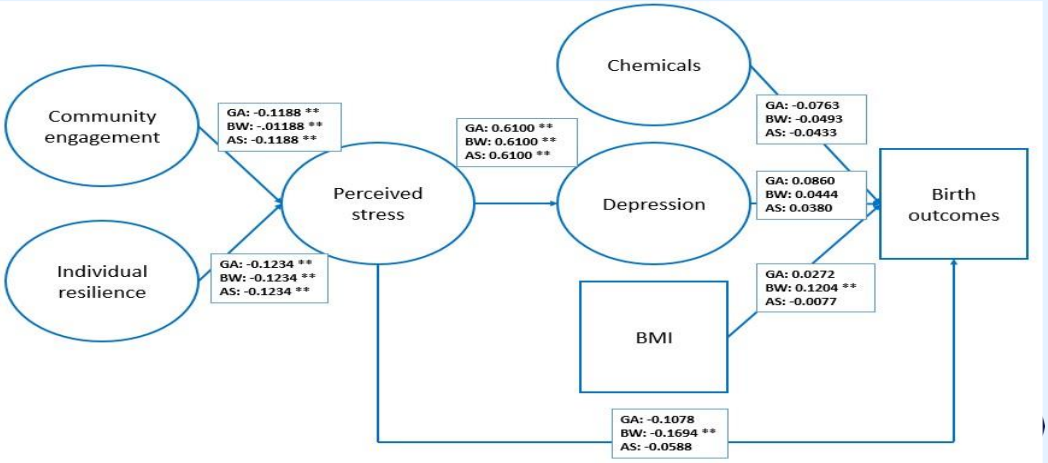

MANUSCRIPT 3

25

International Journal of *Environmental Research and Public Health*

MDPI

Article

The Cumulative Risk of Prenatal Exposures to Chemical and Non-Chemical Stressors on Birth Outcomes in Suriname

Anisma R. Gokoel [1,2,*], Arti Shankar [3], Firoz Abdoel Wahid [4], Ashna D. Hindori-Mohangoo [5,6], Hannah H. Covert [5], Jeffrey K. Wickliffe [7], Emily W. Harville [8], Wilco C. W. R. Zijlmans [2,5] and Maureen Y. Lichtveld [4]

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check for updates

Citation: Gokoel, A.R.; Shankar, A.; Abdoel Wahid, F.; Hindori-Mohangoo, A.D.; Covert, H.H.;

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OVERALL DISCUSSION

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- Hypothesis: "Prenatal exposure to non-chemical and chemical stressors in pregnant CCREOH women negatively impact birth outcomes"

Based upon the results of the aims, the study hypothesis was accepted

- The prevalences of preterm birth (PTB) (15.2%) and low birthweight (LBW) (13.2%) were higher than the regional average of PTB (9.5%) and LBW (10%) of Latin American and the Caribbean countries
- No association was found between prenatal depression and adverse birth outcomes- screening instrument was used instead of clinical diagnosis to assess depression

CCREOH

OVERALL DISCUSSION CONT'D

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- Participants with elevated hair mercury levels (≥1.58ug/g) had a greater risk of giving birth before 37 weeks of gestation compared to women with lower hair mercury levels (≤0.46 ug/g)
- High likelihood of hair mercury exposure in pregnant women of Indigenous (OR 17.9; p≤0.001) and Tribal (OR 3.7; p≤0.00) descent compared to Hindustani women
  - people living in the interior largely depend on riverine fish for a protein source
- No association between the chemical latent construct and any birth outcomes
  - Non-chemical stressors outweighed other effects (dominant role), protective effect of Se

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STRENGTHS AND LIMITATIONS

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- Strengths:
  - first study in Suriname examining the effect of non-chemical stressors and a unique combination of chemical exposures on birth outcomes
  - study population is a reasonably good representation of pregnancies in Suriname (large study population, ethnic and cultural diversity, several socio-demographic factors and the geographic diversity)

- Limitations:
  - psychosocial questionnaires were not validated for Suriname before data collection
  - Edinburgh Depression Scale is a screening tool and not a diagnostic tool

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RECOMMENDATIONS

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Implications for practice:

- A task shifting approach for health care

Implications for policy:

- Strengthen and enforce policies and laws regarding mercury use, ensure adequate monitoring of mercury use in goldmining to protect inhabitants

Implications for science:

- Other risk factors for perceived stress and depression (e.g., unintended pregnancies, domestic violence, and prenatal care utilization, influence of communicable and non-communicable diseases, culture)

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Questions

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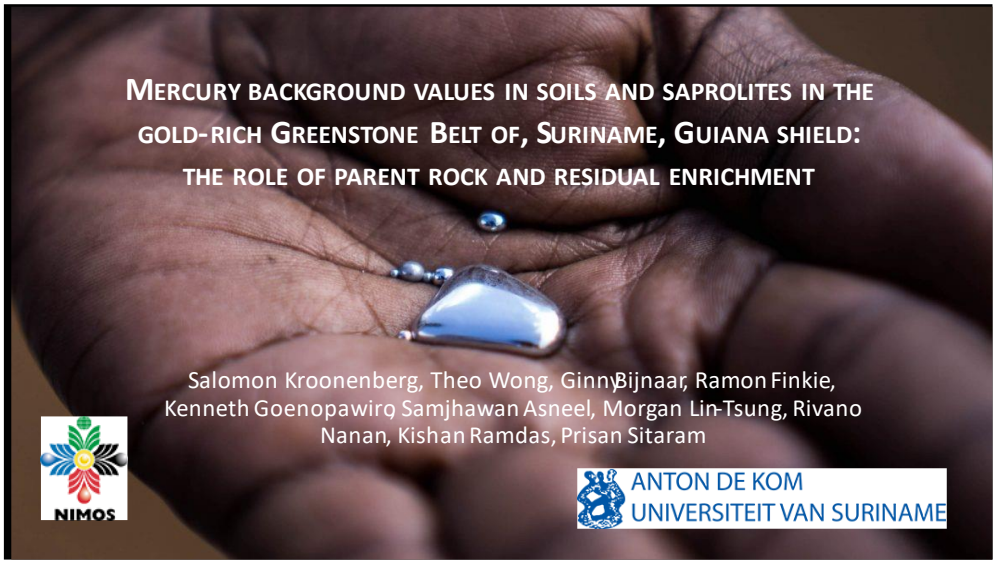
Annex 2:
Presentation 3: "Mercury background values in soils and saprolites in the gold-rich greenstone belt of Suriname, Guiana Shield: The role of parent rock and residual enrichment"



Contract NIMOS-AdeKUS

Assessment of mercury levels within gold bearing geological formations of Suriname

Objective: establish regional mercury background values to be able **to distinguish polluted from unpolluted materials**

Project phases

- Desk study
- Field test sites and laboratory analyses
- Regional survey and laboratory analyses
- Comparison results with existing data on pristine and polluted materials
- Conclusions and implications

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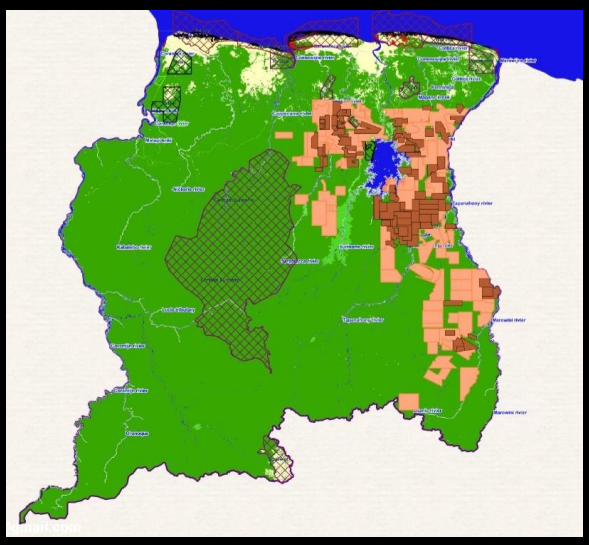
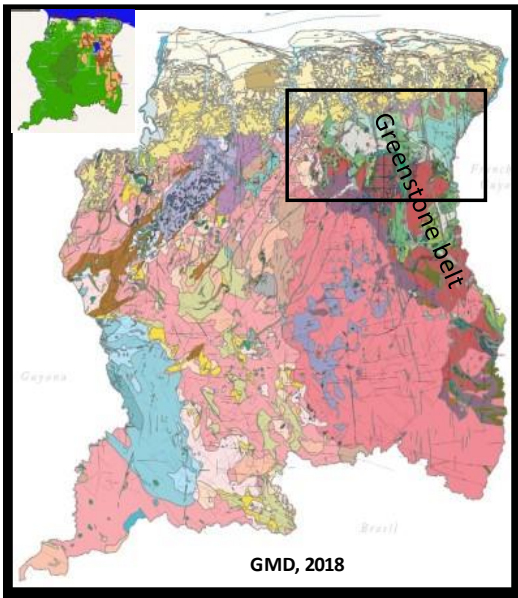
Gold concessions for exploration (orange) and exploitation (brown) Goniniorg





Gold is concentrated in the **greenstone belt**

	Rock type	Age (1 Ga=10⁹y)
Gran Rio Granite	Biotite granite	2.09 Ga
Pikien Rio Pyroxene Granite	Pyroxene granite	2.10 Ga
Rosebel Formation	Qz sandstones, conglomerates	2.12 Ga
Patamacca Granite	Two-mica granite	2.12 Ga
Taffra Schist	Staurolite schists	
Armina Formation	Metagreywackes, phyllites	<2.16 Ga
Sara's Lust Gneiss	Migmatitic gneisses	2.15-2.08 Ga
Kabel Tonalite	TTG-Tonalite, trondhjemite, granodiorite	2.18-2.12 Ga
Paramaka Formation	Phyllite, metachert, gondite	
Paramaka Formation	Metaqzandesite etc	2.14-2.15 Ga
Bemau Ultramafitite	(Meta)gabbro/MetaUltramafite	2.14 Ga
Paramaka Formation	Metabasalt	
Paramaka Formation	Amphibolite	

Kroonenberg et al., 2016

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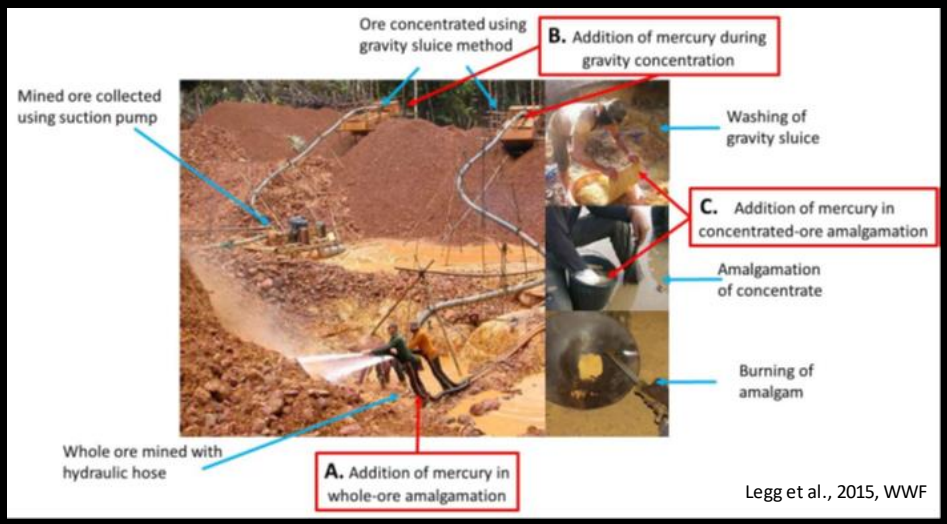
Artisanal small-scale gold mining



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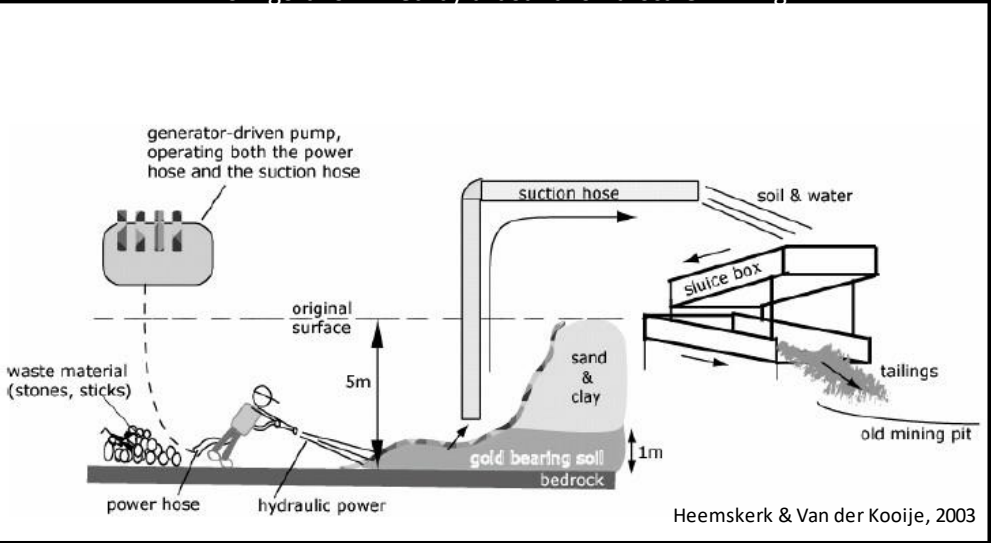
How gold is mined by artisanal smallscale mining



Heemskerk & Van der Kooije, 2003

Phase 1: Three test sites to develop methodology

Field test site 1, Afobaka Road

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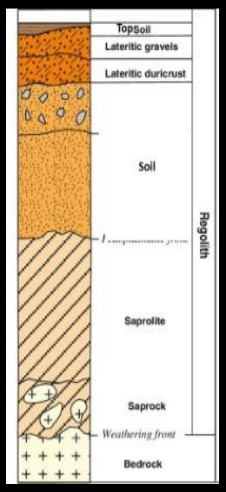
Test site Afobaka Road km 55, 2017: anticlinal fold structure in Paramaka rocks

Classic laterite profile

Leaching of mobile elements Ca, Mg, K, Na



Residual enrichment immobile elements, Fe, Al, Si

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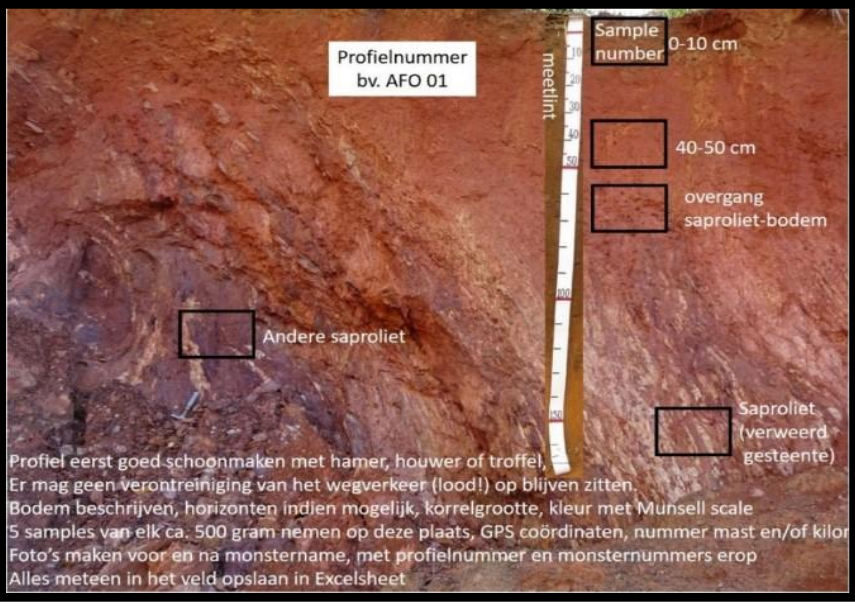
Sampling instructions to field crews



FILAB SURINAME

FILAB mercury analyser

FIMS 100, Flow Injection Mercury System of Perkin-Elmer

Cold Vapour AAS

Detection limit 1 ppb

1 ppb (part per billion)
= 1 ng g^{-1}
= 1 µg kg^{-1}

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Field Test Site 1 Afobaka Road

Panorama pilot site Afobaka Road km 55, 2021

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Hg analyses Test Site 1

FILAB SURINAME

SAMPLE REF.	Hg ug/kg
Quant. Lim.	1.0
AFO-1 boorsample	62.50
AFO-1 0-10cm	51.00
AFO-1 10-40cm	55.10
AFO-1 1-1.10m	49.50
AFO-1 2.30-2.40m	15.90
AFO-1 3.50-3.60m	9.30
AFO-1 6m	1.00

AFO-2 0-10cm	43.60
AFO-2 10-30cm	162.60
AFO-2 1.20m	40.80
AFO-2 2.10m	18.30
AFO-2 3m	19.60

Mercury at test sites AFO1 and AFO-2:
Hg value depends on
(1) Residual enrichment
(2) Concentration in ironcemented layers

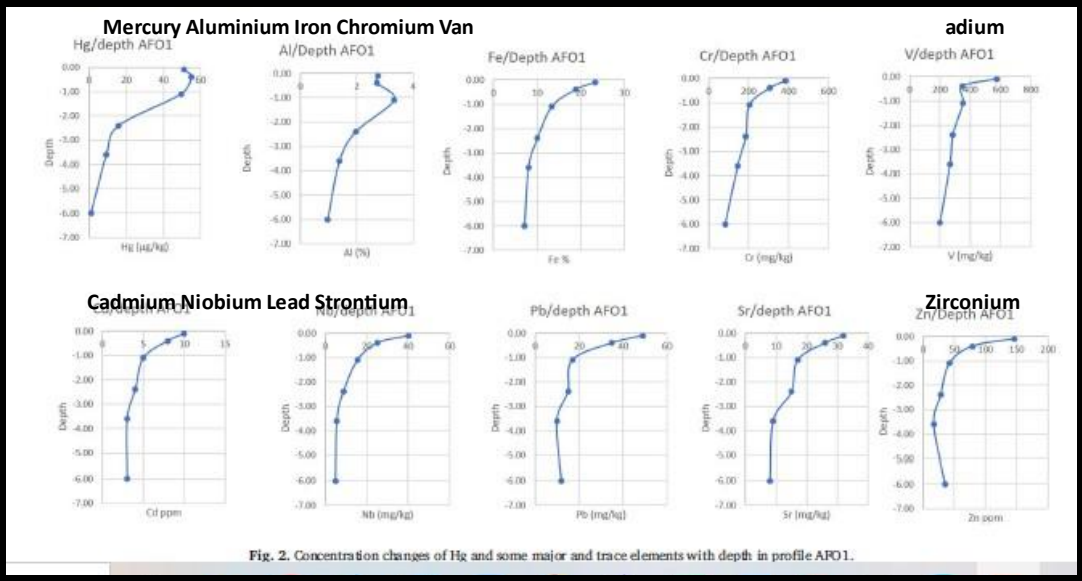

Fig. 2. Concentration changes of Hg and some major and trace elements with depth in profile AFO1.

AFO 1 results: not only Hg analysed, but 40 additional elements:
confirms role of residual enrichment of Hg together with Fe, Cr, V and other elements

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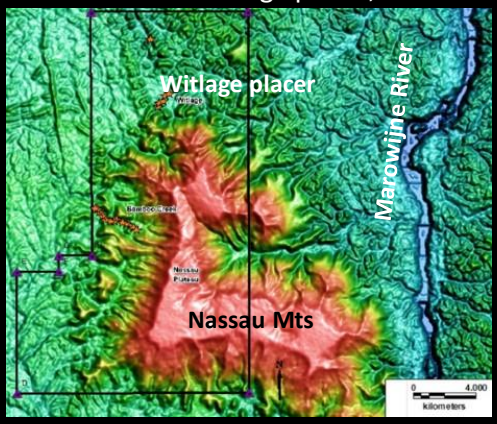
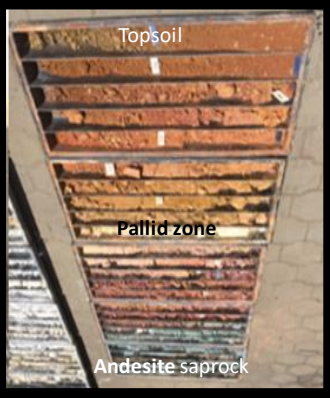
Field test site 2: Witlage placer, Nassau Mountains



Deep exploration drill hole in Paramaka mafic metavolcanics

Photo Kishan Ramdas, courtesy 79North

Hg and multi- element analyses Test Site 2
Nassau Plateau D, core MNA-31, 24 m depth, 79North, Ramdas, 2021



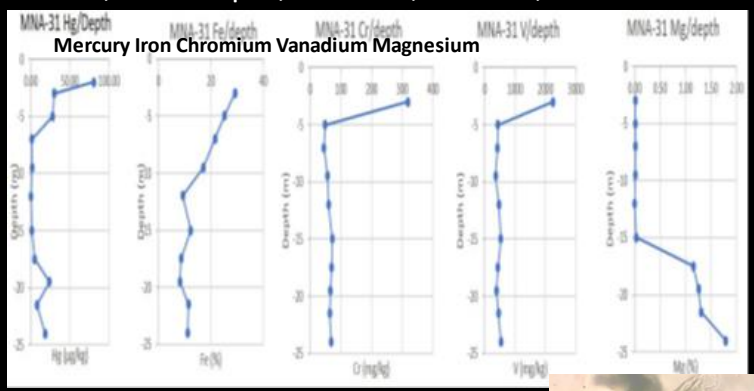


Photo Kishan Ramdas

Confirms residual enrichment Hg together with Fe, Cr, V.
Mg is leached from topsoil but still present in saprock ,
confirmed by chlorite in mineral separates

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Field test site 3: Kriki Neegi (Koemboe Creek, Brownsberg)

Field Test site 3 and Hg analyses

SAMPLE REF.	Hg ug/kg
Quant. Lim.	0.100
PROFIEL 1-001	46.53
PROFIEL 1-002	52.34
PROFIEL 1-003	39.52
PROFIEL 1-004	191.43
PROFIEL 1-005	47.82

PROFIEL 2-001	56.16
PROFIEL 2-002	135.97
PROFIEL 2-003	39.04
PROFIEL 2-004	50.44
PROFIEL 2-005	65.32
Tailing Materiaal	139
Grind verlaten mijn	137.63

Photos Samjhawan Asneel

'Kraskouw' profiles, lateritized slope deposits at the W foot of Brownsberg, Koemboe Creek
Erratic Hg values due to colluvial nature of deposit. No multi-element analyses.

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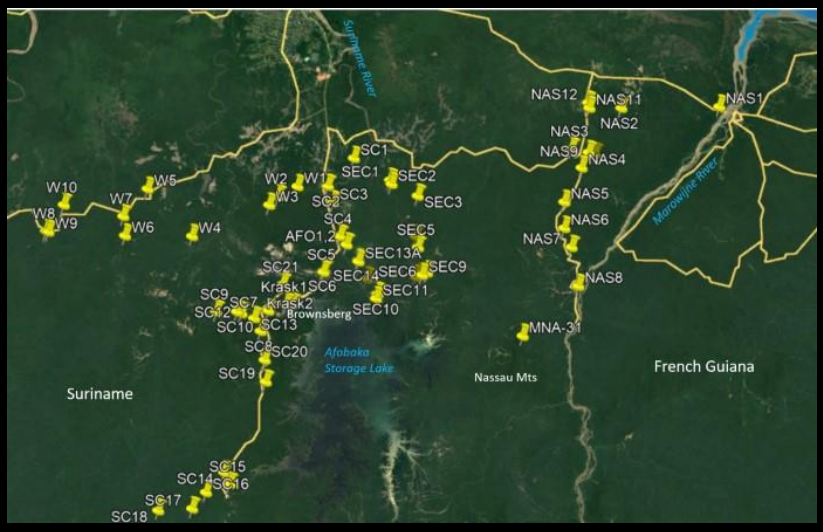
Phase 2: Regional survey Greenstone Belt

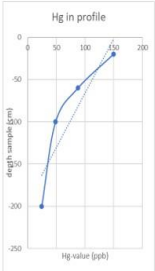


62 Sampling sites along road outcrops, 196 samples collected and analysed

Profile name:	SC 2
Location:	Easting : 709337 Northing : 583660

Figure 3 43 Profile in field SC 2

Table 14 The chart shows de Hg-value (ppb), with correlating depth (cm) of SC 2

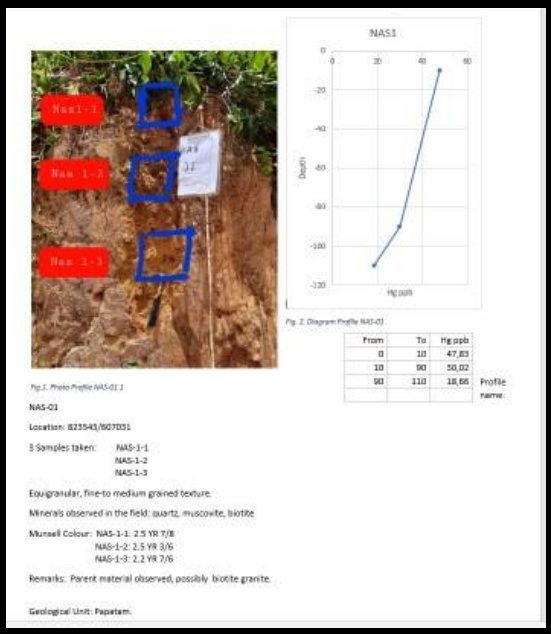


From	To	Hg ppb
10	20	149.73
50	60	87.67
90	100	48.60
	200	24.44

4 Samples taken:

Figure 3 44 sample SC 2.1

Texture :	Medium- grained.
Minerals observed in the field:	Quartz
Munsell Colour:	-
Remarks:	The profile has a brown-orange colour. While the Hg-value decrease with the depth. The area is known for the occurrence of stourolite.
Geological unit	Taffra



Examples of profile descriptionsby students

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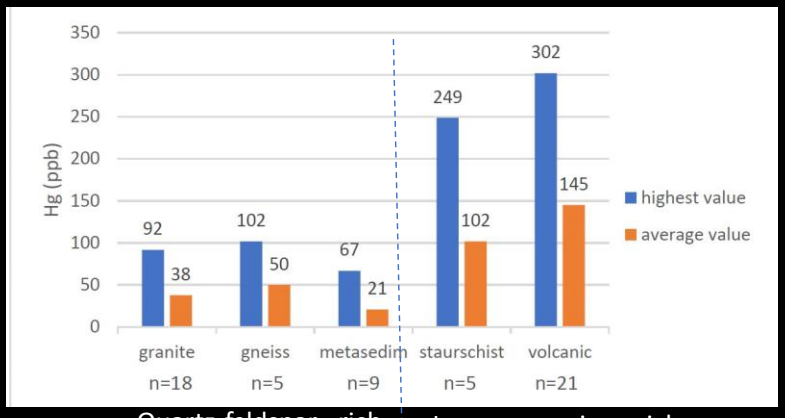
Geol Unit	Unit name	Rock type	Profile Numbers	From	To	Avg
40	Armina	Metaturbidite	NAS6,7,8, SEC 2	65	0	26
35	Gran Rio	Granite	SC17, 18	135	59	87
23	Kabalebo	Charnockite	W8	57	14	36
43	Kabel	Tonalite	SC19,20	80	5	30
42	KwaiKwai	Gneiss	SC14,15, 16	143	24	68
	Papatam	Garnet tonalite	NAS1	48	19	32
44	Paramaka	Phyllite	W2,3	158	1	70
45	Paramaka	Kyanite quartzite	SEC4A,B	17	12	13
46	Paramaka	Meta-andesite	W4,5,SC4,10-13,SEC6,9,10,AFO1,2,KrAB	313	0	71
51	Paramaka	Metabasalt	W6, SC8, 9	215	33	99
52	Paramaka	Amfiboliet	W7 **Goliath** →	807	93	472
38	Patamacca	2Mica granite	NAS 2,4,5,9, 10, 11, 12, SEC 3	178	0	22
37	Rosebel	Metasandstone	SC5, 6, 7, 21, SEC 12	68	0	16
41	Sara's Lust	Gneiss	SCE1 W 1	61	11	32
39	Taffra	Staur gar schist	SC 2,3, SEC1, NAS3, NAS11	249	11	102
24	Wonotobo	Granite	W9, 10	52	4	19
	Pallid zone		SEC 5, 7, 8, 11, 13 14			75

Analytical results per rock unit

Hg values for soils and saprolites per major rock group



Quartz-feldspar -rich Iron-magnesium -rich

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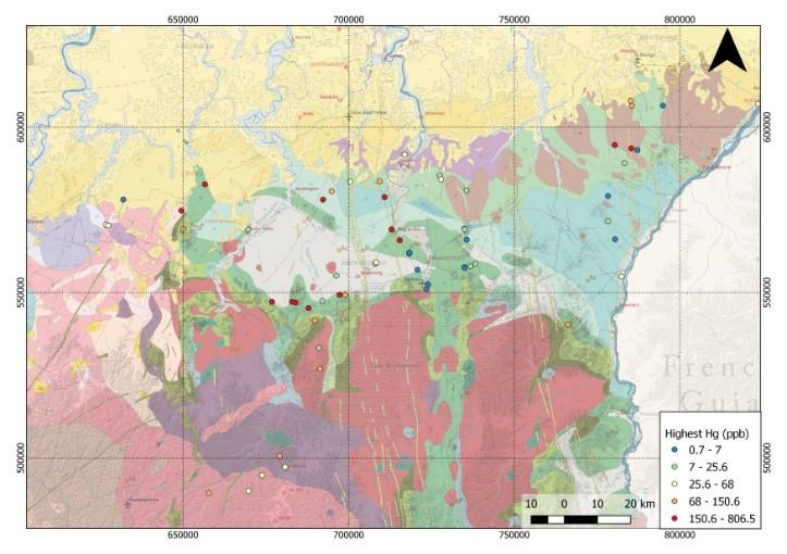
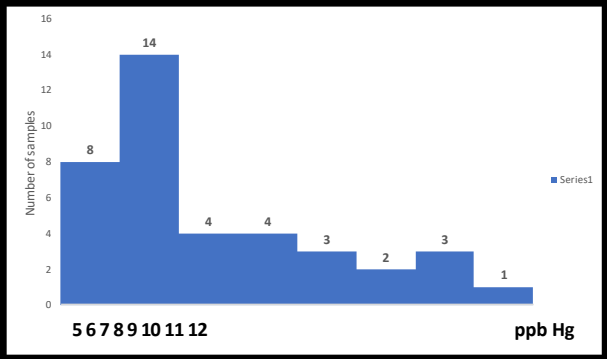


Highest Hg values in individual profiles, plotted on geological map, highest in Paramaka (green)

Phase 3: comparison with existing Hg values from pristine and polluted material



1 ppb (part per billion)
= 1 ng g^{-1}
= 1 µg kg^{-1}

Mercury contents in uncontaminated **hard rock** drill cores from Iamgold Rosebel Gold Mines

Only 39 out of 113 samples have Hg values above detection limit (5 ppb Hg, MDS42)

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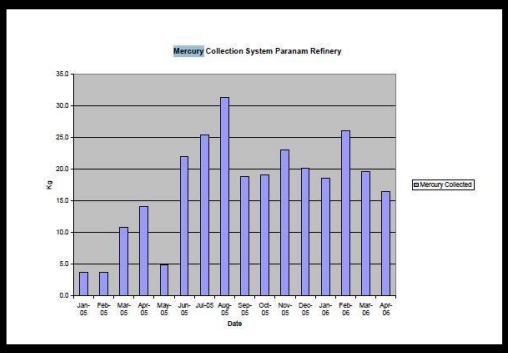
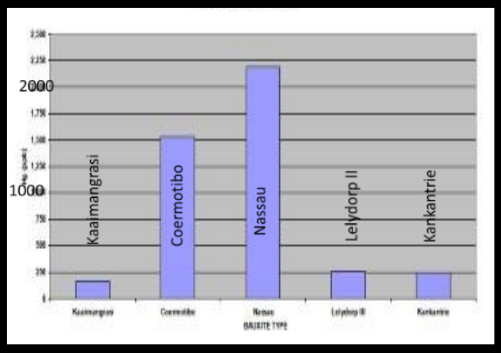
Mercury in bauxite: also residual enrichment



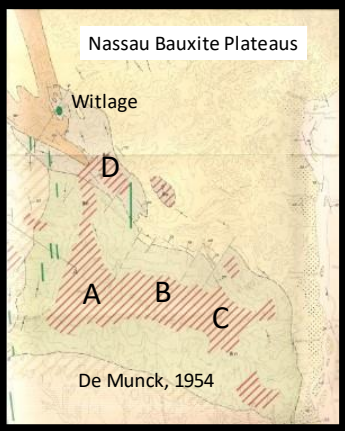
In 2005 Suralco retrieved 200 kg mercury from bauxite refinery

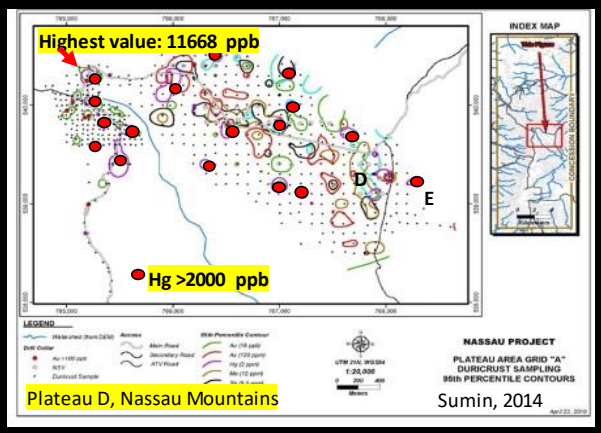


Hg values for different types of bauxite in Suriname

Data: Suralco Source: Bauxite institute Suriname

Mercury values of Nassau Mountains bauxites





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Cinnabar (HgS, mercury ore) in Witlage gold placer, Nassau Mountains

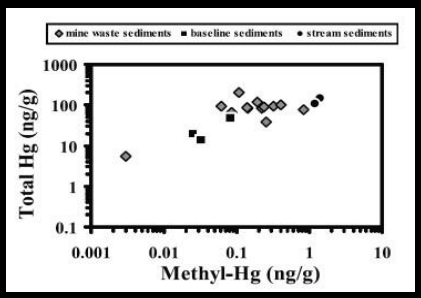
Kroonenberg, 2019, Parbode

Naturalis, Leiden, NL

Headley, 1913; Duyfjes, 1915; IJzerman, 1931; Billiton, 1953; Capps, 2004; Kroonenberg, 2019.

Mercury contents in tailings from Gros -Rosebel gold mines, 2002

Mine waste	5.5-200 ppb Hg
Sediment in streams below mines 110	-150 ppb Hg
Uncontaminatedbaselines (worldwide)	14-18 ppb Hg



Correlation Hg and methyl Hg in Rosebel sediments

Gray et al., 2002, Geoph Res. Letters

Same order of magnitude as in pristine soils and saprolites

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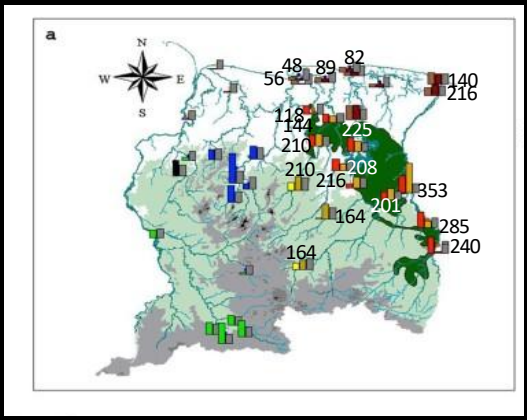
Hg values in Witi Creek gold area, Brownsberg. Arets et al., 2006, ALTERRA

Brownsberg	Hg ppb
Average soil primary forest (n=4)	200
Average soil secondary forest (n=4)	200
Average in between pits (n=7)	200
Average sediment sluice box (n=8)	780
Average sediment in pit (n=6)	250
Average sediment in entrance (n=3)	310
Average sediment exit pit (n=3)	300

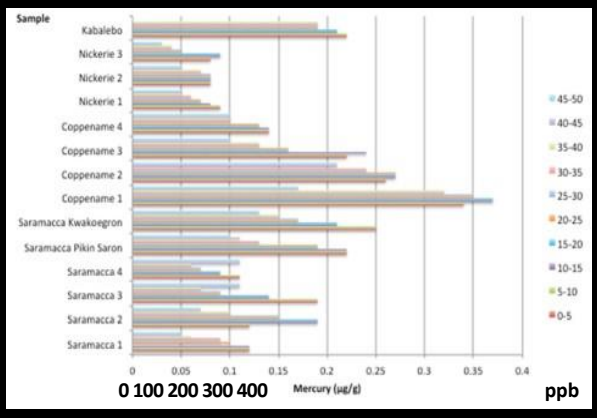
Same order of magnitude as in pristine soils and saprolites

Hg values in river sediments in Suriname

Average contents of Hg (ppb) in river sediments 2004-2005 (data and map from Ouboter et al., 2012, 2015)



Decrease of Hg contents with depth in river sediments in Western Suriname (Ouboter et al., 2015)



Same order of magnitude as in pristine soils and saprolites

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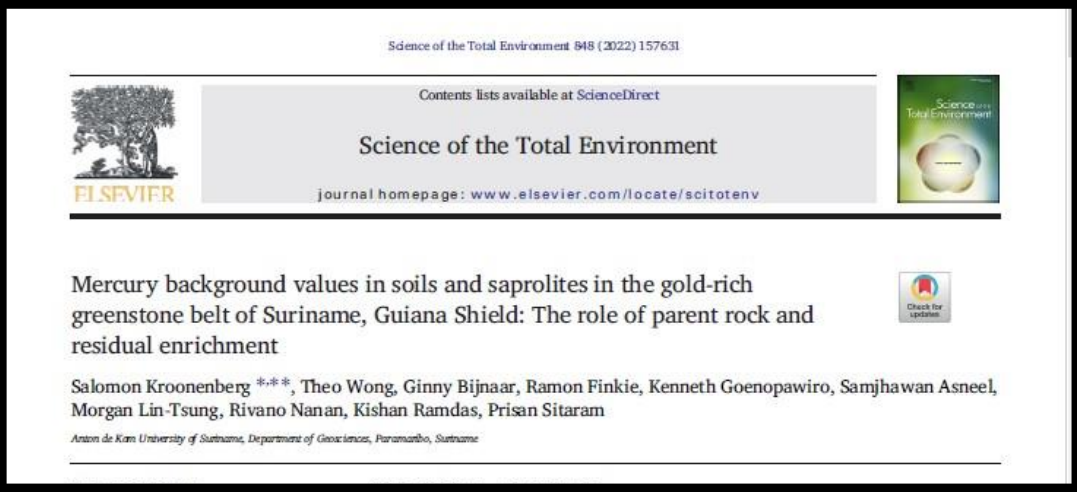
Research published in *Science of the Total Environment*, 2022



Science of the Total Environment 848 (2022) 157631

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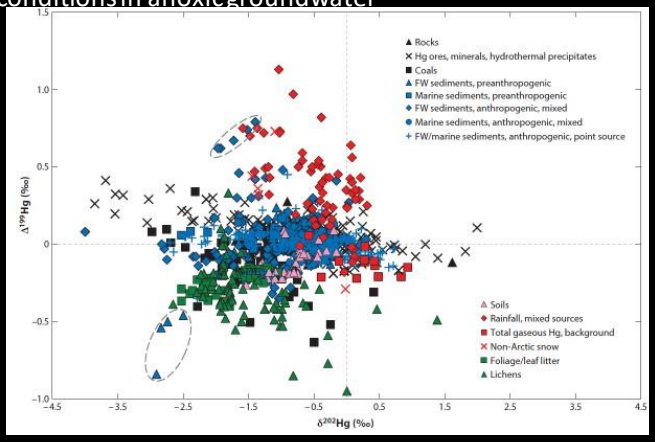
Mercury background values in soils and saprolites in the gold-rich greenstone belt of Suriname, Guiana Shield: The role of parent rock and residual enrichment

Salomon Kroonenberg *,**, Theo Wong, Ginny Bijnaar, Ramon Finkie, Kenneth Goenopawiro, Samjhawan Asneel, Morgan Lin-Tsung, Rivano Nanan, Kishan Ramdas, Prisan Sitaram

Anton de Kom University of Suriname, Department of Geosciences, Paramaribo, Suriname

Possible follow-up research

- Detailed study correlation Hg with clay, org. matter in test profiles
- Hg isotopes, binding with mineralogy (hematite/goethite, Mn oxides)
- Redox conditions in anoxic groundwater



Detailed Hg isotope graph for soils and sediments (Blum et al., 2014)

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UNESCO-IGCP programme, starts summer 2022

Dr. Bridget A. Bergquist (University of Toronto, Canada)

Conclusions

(1) Primary hardrock: low values, Hg < 12 ppb

(2) Topsoils and iron-cemented horizons residually concentrate Hg up to 100-200 ppb, together with Fe, Cr, V. Extreme residual values in bauxite (commonly 2000 ppb, highest 12000 ppb)

(3) Deeper horizons (mottled, pallid zones) are depleted to low levels (Hg < 1 ppb)

(4) Range of values within individual profiles is higher than between profiles

(5) Fe-rich parent rocks have higher Hg in topsoils than quartz-feldspar-rich rocks

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Implications

(1) Unpolluted (top)soils and saprolites have Hg values in the same range as stream sediments and mine tailings. This method is unsuitable to distinguish polluted samples from pristine ones. Probably isotope studies are necessary.

(2) Hg in soil and saprolite is probably not a hazard as long it remains bound to Fe-oxides in oxidized environments. Conversion to methyl-Hg requires reducing conditions e.g. in groundwater and mine pits. So avoid stagnant water in gold-mining areas!

https://www.youtube.com/watch?v=uXEYZ07o8wU