Are Groundwater overextraction and reduced infiltration contributing to Arsenic related health problems near the Marlin mine (Guatemala)?

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An analysis of the monitoring data provided by the mining company *Montana Exploradora de Guatemala* shows that arsenic concentrations are sharply rising in their production well. Arsenic concentrations in some groundwater wells around the nearby Marlin mine fall far above the WHO and North-American and Canadian health standards for drinking water. The alarming concentrations, combined with the elevated arsenic concentration found in urine of people living close to the mine and the scattered reports of arsenic related diseases 1) prove that this aspect was neglected during the initial Social and Environmental Impact Assessment(S&EIA) and its reviews; 2) show that a broader independent research is necessary prior to further groundwater extraction; 3) The causes and extent of arsenic in groundwater should be further investigated in this region.

1 Introduction

Figure 1: Location of the study area in Guatemala

The Marlin gold and silver mine is located in south-west Guatemala, in the Northern part of the San Marcos department (Figure 1). It is both an open pit and underground mine, which uses a cyanide tank leaching process to extract gold and silver (MEG, 2003). After finalization and approval by the Guatemala Governement of the social and environmental impact assessment S&EIA(MEG, 2003) the mining site was developed in 2004 and operations were started in 2005. The mine site was developed by Montana Exploradora de Guatemala, S.A., with support of the International Finance Corporation (World Bank). Montana Exploradora is a daughter company of Glamis Gold, which was acquired in 2006 by the Canadian Goldcorp company. The mine is situated in a mountainous area at an altitude of 2000 m, in a semi-arid mountaineous climate with a distinct rainy sea-

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son. Average yearly precipitation is estimated at 1008 mm, and the average yearly temperature is 25°C. There is a precipitation deficit for the major part of the year resulting in limited groundwater recharge. The region around the mine is used for subsistence agriculture, crops frequently being irrigated with water from the river Riachuelo Quivichil (International, 2010). Around 47% of households (MEG, 2005, p22) has no access to piped water, so depends on ground- and riverwater as a source of drinking water. This means that groundwater quantity and quality are important issues in the region, and also means that water quality should be compared with drinking water standards rather than mining water standards themselves.

1.1 Groundwater extraction

In the S&EIA(MEG, 2003) of the Marlin mine, the only sources of water mentioned are rainy water stored in the tailing deposit, and additional water (up to $0.019 m^3/s$) would be pumped from the Tzalá river.

In contrast to what is stated in the S&EIA, the Marlin mine extracts this water from groundwater, and not from the river. The installed well has a maximum capacity of $18.9 L/s$ (Marlin Engineering and Consulting, LLC *et al.*, 2004). In 2007 a volume of 16 L/s was extracted (MEG, 2008). The expected drop in waterlevel is 30 m after 5 years of operation. However, necessary studies are missing, and this value is only a projection after a 10-day pumping trial(Marlin Engineering and Consulting, LLC *et al.*, 2004) Results herein are interpreted as a homogeneous water bearing layer, although the groundwater is present in "fractioned rocks non-defined patters" S&EIA(MEG, 2003).

1.2 Influence of groundwater extraction on groundwater quality

A typical problem of the overextraction of groundwater layers is a deterioration of the groundwater quality, leading to an increase of the Total Dissolved Solids (TDS). Different mechanisms are possible: intrusion of poorer quality waters, like salt waters (Andrews, 1981) or volcanic waters (Flores-Márquez *et al.*, 2006); oxidation of sulphide bearing minerals (Mossmark *et al.*, 2007). An important element which should be monitored during groundwater extraction is arsenic. Arsenic, which is highly soluble and therefore usually not present in shallow groundwater tables, but only in deeper groundwater: close to the surface arsenic has already leached out of the system, and arsenic pollution can become an issue when deeper groundwater layers are being pumped (eg geothermal groundwater) or when arsenic becomes soluble due to oxidation (due to lowering of the water table. Occurence of arsenic in groundwater is a well known phenomenon (Nordstrom, 2002; Ravenscroft *et al.*, 2009) and has been described worldwide, including in semi-arid volcanic regions which are similar to the mine site (Armienta *et al.*, 2004), where arsenic mobility increased after changes in groundwater flows. Arsenic pollution has also been associated with mining in many countries (Brazil, UK, Ghana, Mexico)(Williams, 2001; Nordstrom, 2002). With respect to this study, one of the critical monitoring wells is 300 m deep and the reported changes of water quality in time (see further) are probably caused by a deep geothermal source where the enterprise was likely drawing water from (International, 2010).

1.3 Health effects of arsenic

Even though the negative effects of arsenic have been known for a long time, the effects only became widely known after large outbreaks of arsenic related diseases in Bangladesh, where these diseases started after the installation of (deep) groundwater pumps in a attempt to reduce water-borne diseases. This action was highly succesfull, but new diseases, especially skin and hair related issues were reported (Chowdhury *et al.*, 2000)

According to a 1999 study by the National Academy of Sciences (National Research Council, 1999), arsenic in drinking water causes bladder, lung and skin cancer, and may cause kidney and liver cancer. The study also found that arsenic harms the central and peripheral nervous systems, as well as heart and blood vessels, and causes serious skin and hair problems. It also may cause birth defects and reproductive problems(Ratnaike, 2003).

The World Health Organization has a limit for arsenic of $50 \mu g/L$ for drinking water. However, this is a very weak limit, since different studies (EPA, 1998; National Research Council, 1999, 2001) show that at this concentration the cancer-mortality risk already is 1 in 100. The WHO has since then recommended to decrease the arsenic limit for drinking water to $10\mu g/L$ (WHO, 1993). In the mean time, the Canadian drinking water guideline has changed the maximum acceptable arsenic concentrations in their drinking waters to this particular level (N.N., 2006).

2 Methodology

To assess whether groundwater quality alterations due to overextraction occured, all data that concerns groundwater quality were collected from different reports (Table 1). Form September,2005 to January, 2006 groundwater samples were analyzed in the SGS laboratory (MEG, 2006, p49). However this lab was not suited to analyse metals with a low concentration (MEG, 2006, p49) Starting from 2006 analyses were conducted at the ACZ Laboratories (Steamboat Springs, Colorado), certified to run low-level environmental samples, resulting in noticeably improved detection limits. Analyses for 2008 were conducted in yet a different lab: SVL, also certified for environmental samples. It should be mentioned that the only wells which have a continuous dataset are the production well MW5 and pit MW3/MW3B.

3 Results

Figure 2 shows the Total Dissolved Solids and the concentration of 5 elements which were monitored in the production well (mw5). From this data it is evident that there has been a continuous increase in most elements, including arsenic. An increase of the arsenic concentration by on average 400% was detected from 2006 to the end of 2009, implying the arsenic concentration doubled nearly every year starting from the beginning of the mine activities onwards.

Figure 3 shows an overview of the different concentrations of arsenic measured in groundwater near the marlin mine for those places where arsenic was above the detection limit. During the monitoring period, pit MW3b and MW8 showed no signs of arsenic pollution. Also the levels in PW7 are below the safe drinking water standards (Smith *et al.*, 2002). On the other hand it is clear that the water in MW5 has passed the safe drinking water standard and that the water from wells MW11 and especially MW10 (located downstream of the mine) exceed arsenic health levels: values of 261 and 46 $\mu g/L$ where detected in MW10 and MW11 respectively

4 Discussion

4.1 Water quality

The water quality has been cleary deteriorating in the production well (MW5) during the time course of groundwater extraction. There is an enormous increase in concentrations of many elements, including arsenic. The high correlation with boron and chloride seems to indicate that the source of arsenic is geothermal, which was also suggested by Goldcorp itself. Two lines of evidence, however suggest that other mechanisms can be involved as well. First the temperature from this well was not significantly different from other wells, and the silica concentrations, which are often elevated in geothermal water sources, were also not higher than those from other sampled wells in this area (International, 2010). Second, the increasing sulphate and dissolved oxygen concentrations cannot exclude the oxidation of arsenic-bearing minerals, like arsenopyrite (Ravenscroft *et al.*, 2009), which are present in the rocks(SRK Consulting, 2004).

Conclusion 1 *Even though the exact mechanism is unknown the extraction of groundwater leads to a very sharp increase in concentration of different elements, including arsenic at the production well. Further groundwater extraction should be ceased until serious geohydrological baseline studies and monitoring stations prove that the impact of further extraction is minimal.*

Even higher levels of arsenic are found in recently opened groundwater monitoring points: up to 0.291 mg/L in MW10 (MEG, 2009).

Conclusion 2 *The data proves that arsenic concentrations in some groundwater layers are far above safe drinking guidelines This is important information regardless of mining. Further research in the area should be conducted to distinguish safe wells from unsafe wells (which are still suitable for washing/...). It also means that care should be taking when installing new wells, especially if these draw water from deeper groundwater layers.*

4.2 Water quantity

Even though the (MEG, 2005, p24) mentions that 'depth to water will be monitored regularly to track any drawdown in the area', no continuous records of groundwater levels are found in any of the annual reports. The limited data seems to suggest that shallow surface groundwater is disappearing: two of the original groundwater monitoring locations (MW2,MW4) were abandoned because they became dry already during the first year of operation (MEG, 2006). The disappearance of 6 water wells was part of a complaint (Latin American Water Tribunal, 2008) by the communities near the mine.

Conclusion 3 *The S&EIA and their reviews failed to recognize the importance of a baseline study, sufficient groundwater monitoring, and a groundwater model, even though the possible negative impacts of overextraction on groundwater quality and quantity were common knowledge known prior to these studies. The monitoring reports also failed to recognize/ the changes in quality of the groundwater.*

4.3 Increased human consumption of arsenic-rich groundwater?

A recent report (Basu & Hu, 2010) shows that people living closer to the mining site had significantly higher concentrations of arsenicin their urine. For this reason the study pointed out that geographic proximity to the Marlin mine is an important predictor of metal exposure. The same study shows that one out of five participants indicate skin-related problems, which is in accordance with a photo report of skin and hair problems in San Miguel Ixtahuacán, the village where the Marlin mine is located (Spring & Guindon, 2009). Different typical arsenic related skin problems: hyperpigmentation, palmar and solar keratosis regularly occured.

Although no scientific data are available, these symptoms raise several questions as to what extent a causal relation between elevated As concentrations in the mining area and health problems does occur. According to a study in San Miguel (van der Hoeven, 2009), skin diseases currently are said to be the second most important cause of death in the local hospital of San Miguel, although no data are provided. Thus, due to the detection of elevated arsenic concentrations in the drinking water, we can not rule out the possibility that mining related activities are directly or indirectly involved into the health effects observed. This definitely stresses the urge for more research into human health risks, as well as the necessity for a more elaborate monitoring of environmental parameters.

Conclusion 4 *The fact that elevated arsenic concentrations are found in groundwater and urine and that arsenic induced diseases seem to be widespread urge for immediate action.*

4.4 Is mining causing arsenic related diseases in the population?

There are 2 basic mechanisms how mining could lead to higher arsenic content in drinking water: 1) the concentration rises as a direct effect of overextraction. 2) If superficial wells are disappearing due to reduced infiltration and/or overextraction a larger share of the water which is consumed will come from deeper wells, potentially richer in arsenic. (Basu & Hu, 2010, p.13) notes that many farmers distrust the river water since the inception of the mine, which may also lead to an increased usage of ground water, where As concentrations are generally higher than in surface water (where it is diluted by precipitation). On the basis of the arsenic concentrations data reported in Figure 3, it is predicted that at least (for groundwater concentrations of 25 µg/L) the estimated lifetime range of

Table 1: Sources of groundwater data

Year	Monitoring locations	Source	Comment
2004	MW2, MW3, MW5	MEG (2005)	Lab unreliable for low metal concentrations
2005	MW2, MW5, G11	MEG (2006)	Lab unreliable for low metal concentrations MW3b replaces MW3, no data provided
2006	MW3b, G11, MW5	CTA (2007)	(only 4th semester)
2007	MW3b, MW5, MW8, MW10, MW11	MEG (2008)	
2008	MW3b, MW5, MW8, MW10, MW11	MEG (2009)	

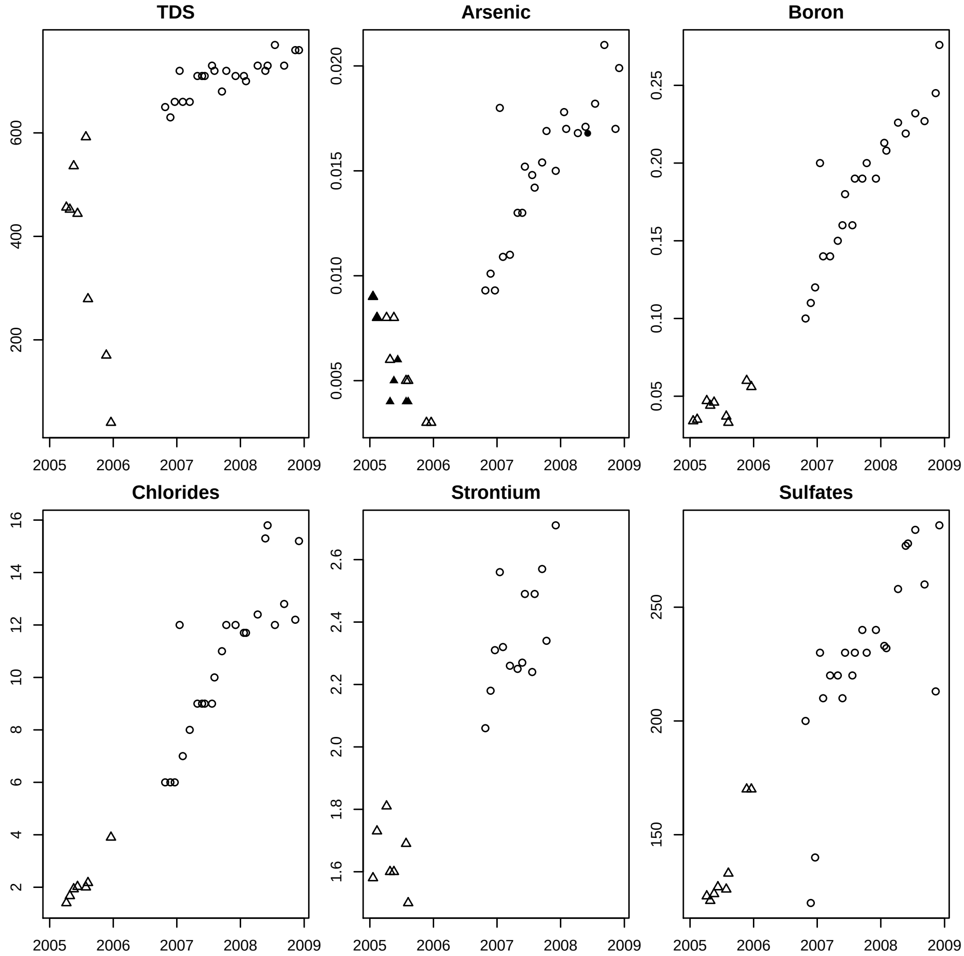

Figure 2: Concentrations of selected elements in production pit mw5. Triangles are samples analyzed in the SGS lab (MEG, 2006); circles denote samples analyzed in the ACZ/SVL labs(MEG, 2007, 2008, 2009). Full symbols indicate total content of a element, hollow symbols denote only the soluble fraction. The choice for the new laboratories starting from the beginning of 2007 was made to improve data quality (with respect to metal detection limits and laboratory contamination issues) and to improve turn-around times.

risk of excess internal organ cancers (in addition to the background lifetime cancer risk) will vary between 8 to 97 cases out of 100.000 exposed persons. As MW11 and MW10 were measured to contain arsenic concentrations of on average 46 and 261 µg/L, respectively, it is very probable that the estimated risk will be far more than the value reported here (Guidelines for Canadian drinking water quality, 2006), given a lifetime (70 years) of chronic exposure to the reported values. For the same reason it is highly probable that the reported claims of skin stains and irritations are directly related to mining related arsenic enrichments of the waterbodies.

Conclusion 5 *The baseline study and monitoring reports are insufficient to guarantee that there is no influence on human health due to groundwater extraction and/or reduced infiltration. To the contrary, their data proves that arsenic concentrations in groundwater are rising due to extraction and the data suggest that superficial wells are disappearing. Both factors may lead to an increased intake of arsenic by the population living close to the mine.*

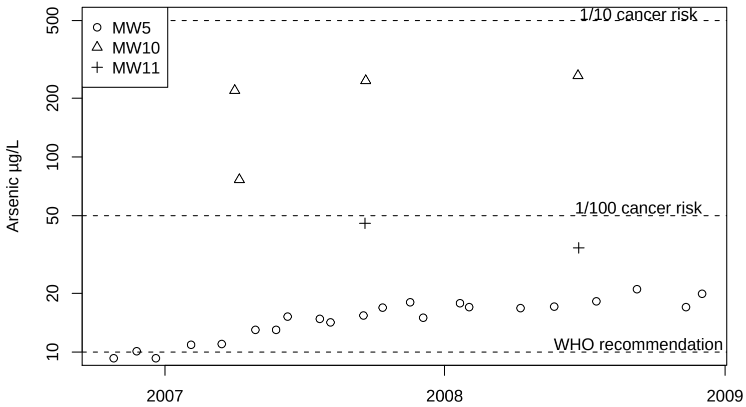

Figure 3: Observed arsenic concentrations (log scale)(MEG, 2007, 2008, 2009) in different pits around the Marlin mine compared to different drinking water standards (Smith *et al.*, 2002). Only data after 2006 has been plotted (reliable), pits [1] have values close to the detection limit and well below safe drinking water and have not been included.

5 Conclusions

Apart from the 5 conclusions given in the discussion, the lack of a detailed baseline study and the limited monitoring performed upto now proves that legislation in Guatemala (as in many other developing countries) can be improved, and that standards for EIA and monitoring efforts should be brought on par with developing countries. On the other hand the fact that monitoring data were publicly available made this study possible, which proves the importance of publicly available, reliable and independent monitoring data. For this reason, one should consider the necessity to organize a truly independent, transparent and scientifically well-founded monitoring system in order to meet these requirements.

References

Andrews, Robert W. 1981. Salt-Water Intrusion in the Costa de Hermosillo, Mexico: A Numerical Analysis of Water Management Proposals. *Ground Water*, **19**(6), 635–647.

Armienta, Aurora, R., Rodríguez, K., Ongley Lois, Helen, Mango, & Romero Francisco, M. 2004. Influence of groundwater flow on arsenic mobility in a limestone aquifer. Zimapán, Mexico. *In: XXXIII International Association of Hydrdogeologists & 7th ALHSUD Congress "Groundwater Flow Understanding: from Local to Regional scales", Zacatecas, Mexico.*

Basu, Niladri, & Hu, Howard. 2010 (May). *Toxic Metals and Indigenous Peoples Near the Marlin Mine in Western Guatemala.* Tech. rept. Physicians for Human Rights.

Chowdhury, U K, Biswas, B K, Chowdhury, T R, Samanta, G, Mandal, B K, Basu, G C, Chanda, C R, Lodh, D, Saha, K C, Mukherjee, S K, Roy, S, Kabir, S, Quamruzzaman, Q, & Chakraborti, D. 2000. Groundwater arsenic contamination in Bangladesh and West Bengal, India. *Environmental Health Perspectives*, **108**(5), 393–397. PMID: 10811564 PMCID: 1638054.

CTA. 2007. *Informe de Cumplimiento ambiental Mina Marlin 4to Trimestre, 2006.* Tech. rept. Consultoria y Tecnología Ambiental, S.A.

EPA, US. 1998. *Special Report on Ingested Inorganic Arsenic - Skin Cancer; Nutritional Essentiality.* Tech. rept. EPA/625/3-87/013. US Environmental Protection Agency, Washington, DC.

Flores-Márquez, E. Leticia, Jiménez-Suárez, Gabriel, Martínez-Serrano, Raymundo G., Chávez, René E., & Pérez, Daniel Silva. 2006. Study of geothermal water intrusion due to groundwater exploitation in the Puebla Valley aquifer system, Mexico. *Hydrogeology Journal*, **14**(7), 1216–1230.

International, E-Tech. 2010. *Evaluation of predicted and actual water quality conditions at the Marlin mine, Guatemala. 87 p.ational (2010). Evaluation of predicted and actual water quality conditions at the Marlin mine, Guatemala.* Tech. rept. E-Tech International.

Latin American Water Tribunal. 2008. *Public Hearing: Open pit mining in the Cuilco and Tzala river basins. Sipacapa and San Miguel Ixtahuacan Districts, San Marcos Department. Guatemala.*

Marlin Engineering and Consulting, LLC, SRK Consulting, & Vector Colorado LLC. 2004. *Installation Report - Water Supply Well PSA-1.* Tech. rept. S.A. Montana Exploradora de Guatemala.

MEG. 2003. *Executive Summary. Social and Environmental Impact Assessment Study Marlin Mining Project. 27pp.* Tech. rept. S.A. Montana Exploradora de Guatemala.

MEG. 2005. *Environmental and Social Performance Annual Monitoring Report 2004.* Tech. rept. Montana Exploradora de Guatemala, S. A. , International Finance Corporation.

MEG. 2006. *Environmental and Social Performance Annual Monitoring Report 2005.* Tech. rept. Montana Exploradora de Guatemala, S. A. , International Finance Corporation.

MEG. 2007. *Environmental and Social Performance Annual Monitoring Report 2006.* Tech. rept. Montana Exploradora de Guatemala, S. A. , International Finance Corporation.

MEG. 2008. *Environmental and Social Performance Annual Monitoring Report 2007.* Tech. rept. Montana Exploradora de Guatemala, S. A.

MEG. 2009. *Environmental and Social Performance Annual Monitoring Report 2008.* Tech. rept. Montana Exploradora de Guatemala, S. A.

Mossmark, Fredrik, Hultberg, Hans, & Ericsson, Lars O. 2007. Effects of groundwater extraction from crystalline hard rock on water chemistry in an acid forested catchment at Gårdsjön, Sweden. *Applied Geochemistry*, **22**(6), 1157–1166. Selected Papers from the 7th International Conference on Acid Deposition, Prague, Czech Republic, 12-17 June, 2005, 7th International Conference on Acid Deposition.

National Research Council. 1999. *Arsenic in Drinking Water.* Washington DC: National Academy Press.

National Research Council. 2001. *Arsenic in Drinking Water. Update 2001.* Washington DC: National Academy Press.

N.N. 2006. *Guidelines for Canadian drinking water quality: Guideline Technical Document – Arsenic.* Tech. rept. Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment.

Nordstrom, D. Kirk. 2002. Worldwide Occurrences of Arsenic in Ground Water. *Science*, **296**(5576), 2143–2145.

Ratnaike, R.N. 2003. Acute and chronic arsenic toxicity. *Postgraduate Medical Journal*, **79**, 391–396.

Ravenscroft, Peter, Brammer, H., & Richards, K. S. 2009. *Arsenic pollution: a global synthesis.* John Wiley and Sons.

Smith, Allan H., Lopipero, Peggy A., Bates, Michael N., & Steinmaus, Craig M. 2002. Enhanced: Arsenic Epidemiology and Drinking Water Standards. *Science*, **296**(5576), 2145–2146.

Spring, Karen, & Guindon, Francois. 2009 (02). *San Miguel Health Harms.* Tech. rept. Rights Action and COPAE.

SRK Consulting. 2004 (February). *Geochemical Characterization of Waste Rock at the Marlin Project, Guatemala.* Tech. rept. Marlin Engineering and Consulting LLC, Vancouver, B.C.

van der Hoeven, Julia. 2009 (june). *Health problems due to working and living in mining areas: Case study San Miguel Ixtahuacan.* MSc. thesis, Universiteit Antwerpen, Belgium. (in Dutch).

WHO. 1993. *Guidelines for Drinkingwater Quality*. Vol. . Volume 1: Recommendations. Geneva: World Health Organisation.

Williams, M. 2001. Arsenic in mine waters: an international study. *Environmental Geology*, **40**(3), 267–278.