IMPACT ASSESSMENT CASE STUDIES FROM SOUTHERN AFRICA

Benjamin Mapani, Rainer Ellmies, Bohdan Křibek et al

Client: Ministry of Youth and Sport, Government of the Republic of Namibia

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HUMAN HEALTH RISKS ASSOCIATED WITH HISTORIC ORE PROCESSING AT BERG AUKAS, NAMIBIA

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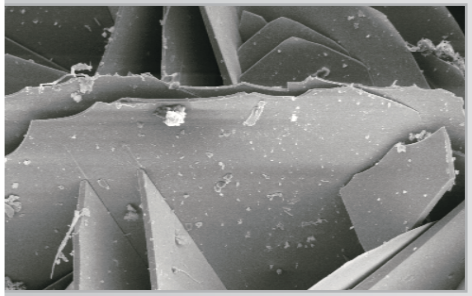

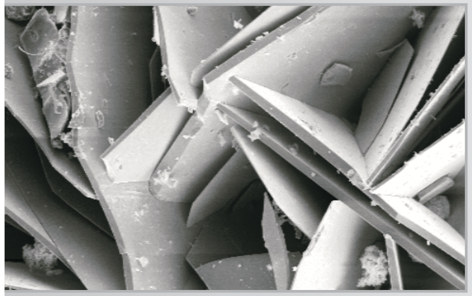

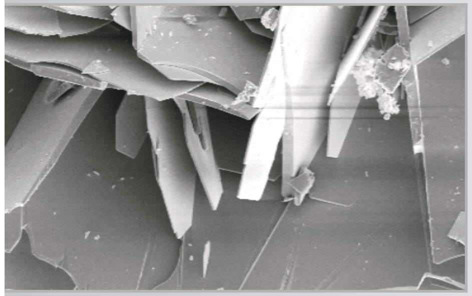

Aims of the Project

Berg Aukas was a lead-zinc-vanadium mine that was operational on-and-off from 1920 into the 1970s, and stopped operating in 1979. Subsequently the area was used mainly for agriculture and the abandoned mine buildings were used as a Youth Training Centre. In 2005 and 2007 comprehensive environmental-geochemical surveys were conducted at the abandoned mine to analyse the contamination of water, soils, and crops. This was to determine the effect of mining and processing on the environment and to formulate recommendations to ensure protection of the residents and students as well as the environment at large.

Over twenty different heavy metal toxins can impact human health. The research was aimed at creating awareness of these pollutants, supporting decision-making and working out measures for remediation where critical heavy metal contaminations were identified.

Brief description of the development

The lead-zinc-vanadium deposit of Berg Aukas was discovered in 1913. Mining started in 1920 and was terminated at the groundwater level in 1928. In 1950 the mine was reopened and vanadinite and sulphide concentrate were produced and roasted on site. The Berg Aukas mine was used as a Youth Training Centre after the early 1990s by the Government of Namibia. The main activities were livestock and horticultural farming, with seasonal cereal crops. This project focussed on understanding the level of contamination of soils and groundwater from previous processing of ores up to 1979 when the mine closed. The main aim was to understand if there were any health risks to the food that was grown in the area.

Remnants of two waste rock heaps are located directly on the area of the former mining and metallurgical complex (Figure 1).

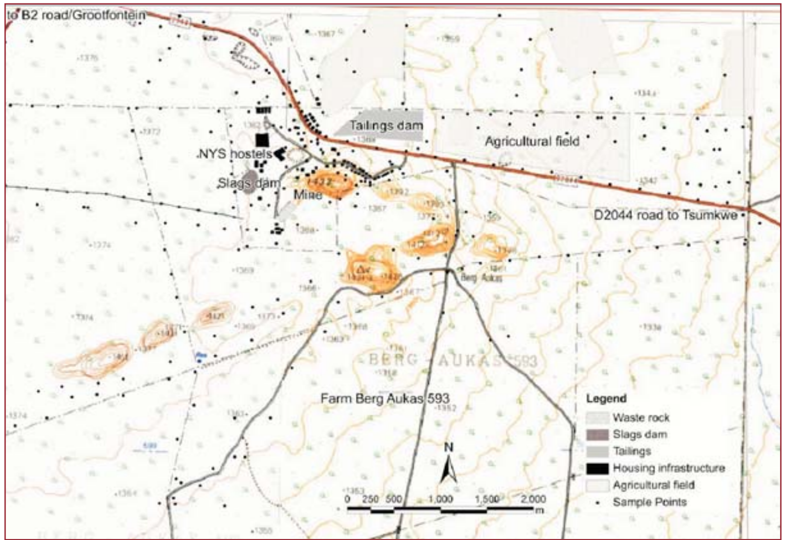

Figure 1. Location of Berg Aukas Mine, west of Grootfontein showing the mining complex, tailings dam and agricultural fields.

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Brief description of the development

The total amount of material deposited in waste rock heaps is estimated at 91,680 m^3. The slag deposit is located within the central mining area. The slag was used for the construction of local roads and therefore this material is widely disseminated throughout the area although it contains heavy metals not suitable for such works. At present the sealing is eroded and the slag deposit represents an important source of dust and heavy metal contaminants. The tailings (slimes) dam is located north of the mining area. The total volume of slimes is estimated at 343,500 m^3. Tailings material has been spilled in larger quantities into adjacent ephemeral streams.

Nature of the project

The project at Berg Aukas consisted of sampling groundwater, soils, grasses and crops grown in the area, to assess the level of contamination by heavy metals from the processing of sulphide ores. This was to find out if the area was safe for human habitation and crop cultivation.

Project phases & timeframes

The area was initially sampled on a coarse grid, which showed severe contamination. These results were brought to the attention of the National Youth Service, who recommended that a detailed study be undertaken. This was completed in September 2007.

Figure 2. Tailings (slimes) dump (left) and waste rock dump (right) at Berg Aukas.

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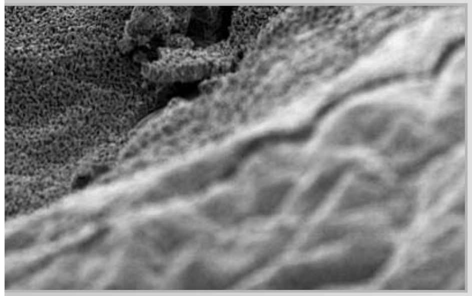

Dimensions of the project

The area affected by the pollution is approximately 20 square kilometres. This includes the farm land to the east of the Berg Aukas complex (Figure 1).

Social considerations

The major social consideration in this area was the loss of livelihoods by farmers and the National Youth Service (NYS) training centre which was affected by relocation. A number of casual labourers who worked at the NYS had to lose their jobs. Produce from Berg Aukas was marketed at the towns of Grootfontein, Tsumeb and Otavi. Relocation of the farming activity and training camp to Rietfontein, nearby, would not greatly alter the marketing of the agricultural produce.

EIA process

This project was initially begun as a scientific study to help map the abandoned mines in Namibia and assess the risks to the physical and biological environment. The study's first results showed that the area posed a great danger to human health. These results were then communicated to the workers and society leaders in the Berg Aukas area, including farmers, who were advised of the contamination and level of pollution on their various tracts of land. Alternatives for farmers were provided, whereas the most affected area, the NYS hostel in the old mine buildings, was recommended to be abandoned.

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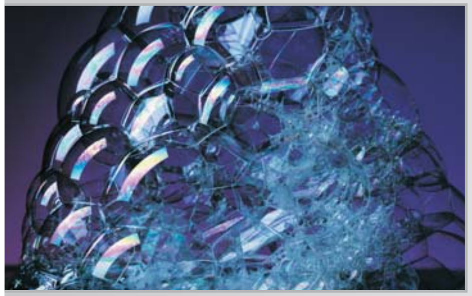

The project

A. Hydrogeological aspects, water sampling and analyses

Water samples were collected from nineteen sample sites including boreholes (14), open wells (3), a spring and the NYS Irrigation project (Figure 3). In total thirty water samples were collected and assessed for concentrations of Al, Ca, Fe, K, Mg, Mn, Na, Si and Ti. Trace elements (As, B, Ba, Be, Cd, Co, Cr, Cu, Li, Ni, Pb, Sc, Sr, V and Zn) were also assessed.

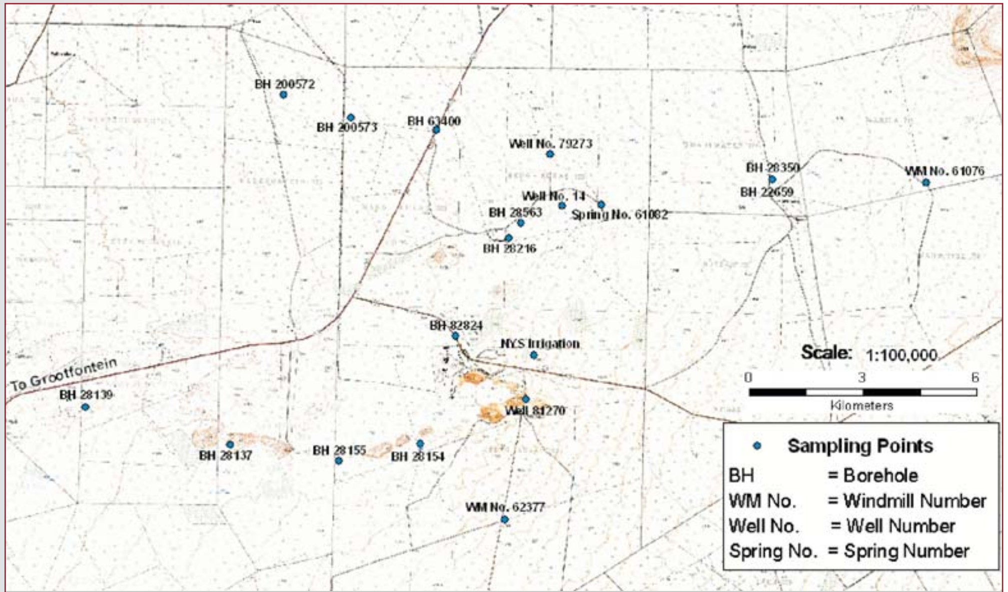

Figure 3. Groundwater sampling points around the Berg Aukas area.

The pH for the water samples range from 6.8 to 8.1. The Namibian Guideline Values for drinking water (DWA, 1999) of Group A (excellent quality) range between pH 6 and 9. The water samples show electrical conductivities ranging from 74 to 393 mS/m. The limits for water of excellent quality (Group A) and of good quality (Group B) are 150 mS/m and 300 mS/m respectively. Consumption of water above 300mS/m (Group C) is considered as a low health risk.

B. Soil sampling and analyses

Methodology

The northern and northeastern parts of the area are covered by soils that contain massive layers of slag and tailings (Figure 1). Six tailings and slag samples as well as 19 soil samples were collected around Berg Aukas in 2005. More thorough sampling was carried out in 2007. 240 top soil samples and 20 background samples were collected. A topsoil sample, collected from the first 3 cm on the surface, reflects eventual contaminations by dumping, spilling and airborne transport. Background samples, taken at a depth of 60 to 80 cm, are necessary for determination

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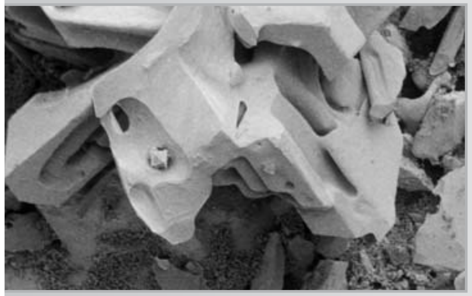

The project

of the seepage of contaminants through the upper layers (mobility) and the detection of eventual natural mineralisations (deposits).

The tailings material contained very high amounts of zinc, vanadium, cadmium, arsenic and mercury. In contrast, the lead concentrations were low. Approximately 18 wt. % of the tailings consists of particles of less than 8µm in diameter (PM_8). These particles pose the most serious health effects as they can enter the lungs.

The slag is rich in zinc, lead, vanadium, copper and arsenic. The amount of PM_8 particles in the slag dust is low (1.3 wt.%).

Arsenic
In the lower soil horizon, contents of arsenic are generally low. Higher concentrations (> 2.6 ppm) were detected in the area of the former mining and processing complex and eastward (downwind) of the slime dams. The elevated concentrations trace back to an infiltration of arsenic-rich solution from the top soil. The median content of As in the topsoil is one order higher (4.99 ppm) when compared with the lower soil horizon, and maximum values are two orders higher (363 ppm).

Cadmium
Concentrations of cadmium in lower soil horizons are very low. Two areas of slightly higher cadmium values (from 2.3 to 5.3 ppm Cd) are located in the former mining and metallurgical complex. The cadmium concentration in the upper soil horizon is much higher (median: 5.4 ppm, maximum value: 387 ppm). It is important to note that elevated concentrations of cadmium in the upper soil horizon encircle the whole area of Berg Aukas and extend towards the east. The large-scale contamination cannot be explained by dust fall-out from mining operations and slime deposits. It is probably a result of emissions from roasting of ores in the past.

Copper
Contents of copper in the lower soil horizon are relatively low (median: 14 ppm), which correspond to the low values of copper in ores. Concentrations of copper in surface soils range from 6 to 327 ppm (median: 28 ppm) and they are only slightly higher compared with the lower soil horizon. The distribution of Cu values can reflect both the position of ore bodies as well as the extent of contamination from surface.

Lead
Lead concentration varies in the top soil of the study area from background values of approximately 20 ppm to more than 33,800 ppm. The highest concentrations above 10,000 ppm (1% to 3,4% Pb) are restricted to a small area in the central and southwestern part of Berg Aukas, probably from mainly gaseous and particle emissions derived from processing, roasting and smelting of ore.

Mercury
Slightly elevated values of mercury occur in the lower soil horizon (0.08–0.19 ppm). No relation is observed between the distribution of mercury and of the position of ore bodies. Mercury concentration in the upper soil reaches a maximum value of 6.9 ppm. Mercury is known to represent highly volatile products of ore roasting and smelting. Elevated concentrations of mercury in the upper soil horizon predominantly reflect in-situ roasting. Fossil fuels used for ore roasting might be a source of the mercury in soils.

Vanadium
Contents of vanadium in the lower soil horizon are low although Berg Aukas ores were mined for

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The project

vanadium. No relationship was found between the distribution of vanadium in the lower soil horizons and the position of ore bodies. The concentrations of vanadium in topsoil are much higher but still relatively lower compared with the maximum values for Zn or Pb. This is probably due to the low volatility of vanadium during ore roasting.

Zinc

While the average background value is 75 ppm, the values vary between 107,000 and 377,000 ppm for the historical smelting area in central Berg Aukas. The topsoil of the smelting area contains 10 to 38% zinc, which is up to three times more zinc then the originally mined ores. Concentrations are very high in the whole National Youth Training Centre and the settlement (1,000 to 50,000 ppm). Large-scale contamination of the whole Berg Aukas area can be attributed to the roasting of ores in the past and by dust fall-out from slimes dams and slag deposits.

The concentrations of trace metals in soils in the study area were compared with the guideline or trigger values from Canada and Germany. The guidelines vary for agricultural, commercial and industrial land uses. Concentrations of metals above these limits are likely to be associated with adverse health effects.

C. Analyses of plant samples

Agriculture in the Berg Aukas area is mostly based on livestock and crops. Therefore different grass species were collected from grazing lands, and samples of maize (grains), cassava (leaves and bulbs) and sweet potatoes (leaves and bulbs) were collected from fields to the east of the settlement. Additionally 30 rhizosphere samples were collected from a depth of 0-30 cm.

The samples were processed and concentrations of As, Cu, Pb and Zn were compared to World Health Organisation limits.

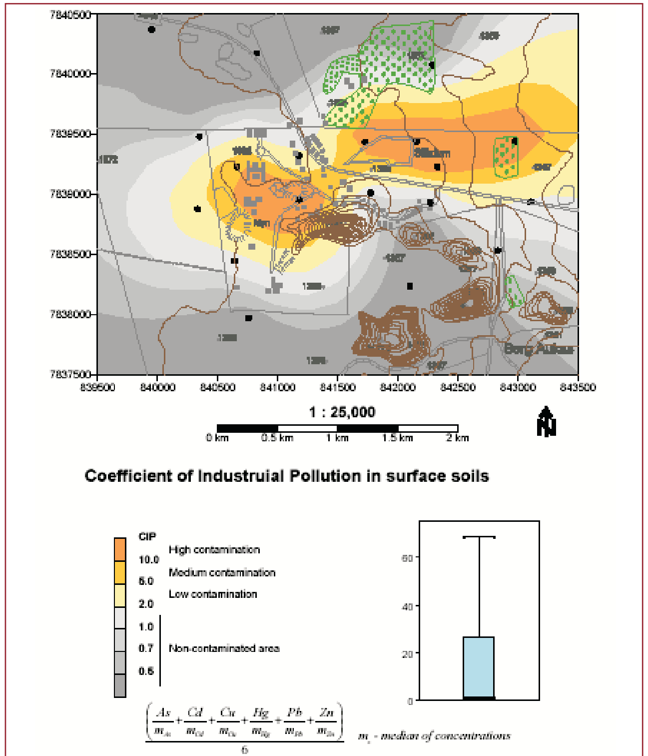

Figure 4. Coefficient of industrial pollution for Berg Aukas (aggregate values of heavy metal concentrations in soils).

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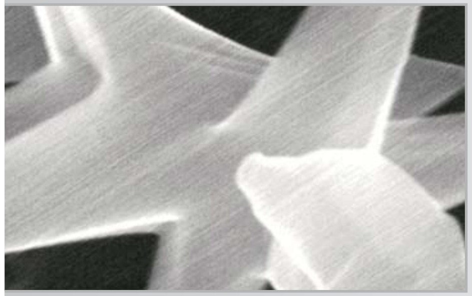

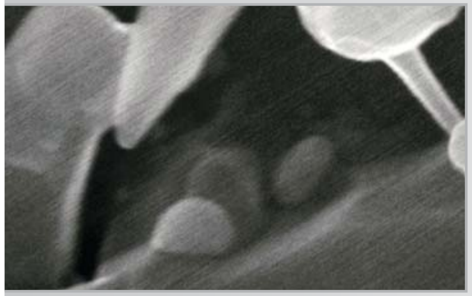

EIA process followed

The median and maximum values for Zn in the set of grass samples (202 and 818 ppm respectively) are in excess of the Czech limits for permanent grass cover (Zn = 35.2 ppm). More than a third of the sampled grass species show Pb concentrations above the Czech limits for dry forage. The highly contaminated samples were collected mainly in the vicinity of the slime deposit and the former processing plant.

The analysed cassava and sweet potato leaves as well as roots are characterized by As, Pb and Zn values in excess of WHO limits for food. The maximum concentrations in cassava leaves are for Pb 185 times higher, Zn almost 9 times higher and As almost 2 times higher than the WHO limits. Maximum values in sweet potato leaves exceed the WHO limits for Pb (460 times), Zn (17 times) and As (almost 5 times). All cassava and sweet potato roots have Pb contents above the WHO limits and two thirds of cassava root samples are characterized by Cu values above the WHO limits. Furthermore, WHO limits for As and Zn are exceeded for two thirds and one third of the sweet potatoes respectively.

Health effects of the major pollutants

The analytical results demonstrate contamination with respect to arsenic, cadmium, copper, lead, mercury, and zinc.

Health effects of permanent exposure to arsenic are, among other things, skin damage such as keratosis and blackfoot disease, (skin, lung, bladder, kidney) cancer, increased infant mortality, and neurological problems. Cadmium is an acute toxin and carcinogen, and poisoning is manifested in lungs, kidneys and bones. Cadmium causes a disease which is known in Japan as "Itai-itai" (pain). Patients suffer from pain in joints, also experience lumbago pains, pseudo fracturing of bones, skeletal deformation and renal dysfunction.

Once absorbed, copper is distributed primarily to the liver, kidneys, spleen and heart. Individuals with copper toxicity show an abnormally high level of copper in the liver, kidneys, brain, eyes and bones. Acute toxicity of ingested copper is characterized by abdominal pain, diarrhoea, vomiting, tachycardia and a metallic taste in the mouth.

Lead is absorbed into the body following inhalation or ingestion. Children absorb lead much more efficiently than adults do after exposure, and ingested lead is more readily absorbed in a fasting individual. Adults distribute about 95% of their total body lead to their bones, while children distribute about 73% this way. Lead can cause irreversible brain damage, seizure, coma and death if not treated immediately. The Central Nervous System becomes severely damaged at lead concentrations starting at 40 mcg/dl in blood, causing a reduction in nerve conduction velocities and neuritis.

Mercury exposure can result in a wide variety of human health conditions. The degree of impairment and the clinical manifestations that accompany mercury exposure largely depend upon its chemical state and the route of exposure. While inorganic mercury compounds are considered less toxic than organic mercury, inorganic mercury that is absorbed is readily converted to an organic form by physiological processes in the liver.

Zinc is a trace element essential in plants and animals, but high exposure may cause neuropathy, dehydration, growth retardation, anaemia, and nausea.

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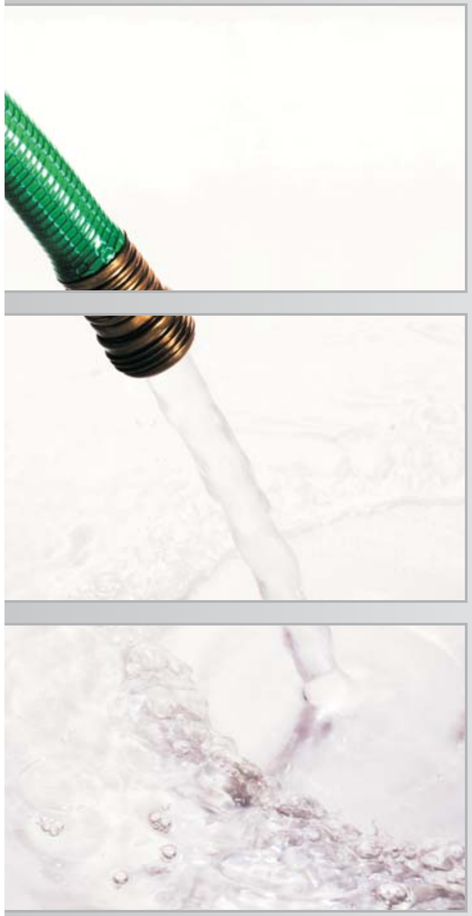

Conclusions

The study shows that most parts of Berg Aukas are severely contaminated (Figure 4) with lead, zinc, cadmium, arsenic and vanadium. The results point to critical contamination of the surface soils in the historical processing area where the ores were smelted. The abandoned mine tailings and slag have been left unattended since 1979. As such the effect of rainfall and wind on the environment has ensured that even areas that were once further away from the mining site have now been affected by heavy metal pollution.

Decision-making process

Due to the nature of our study, and the factual data that we provided to the National Youth Service, the Government of Namibia agreed unanimously to relocate the National Youth Service training camp to Rietfontein.

Monitoring & compliance auditing

The monitoring involved in this project involved the re-sampling of cash crops between 2006-2007 and also re-sampling of groundwater. This showed that the pollution in the soils was much more severe than was originally anticipated, partly because of the long time that the tailings were left unremediated after mine closure. In order to minimise future impacts, the tailings dump would need to be covered by good clay soil that would prevent further wind and water erosion.

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Main elements of excellence in this EIA

The project succeeded in assuring the safety of human beings; otherwise they would have been living in areas which are highly contaminated. Another good aspect was the working relationships between the study group, the community in Berg Aukas and the Government of Namibia, which appreciated the gravity of the problem and facilitated funds to relocate the National Youth Service Training Camp from Berg Aukas.

Lessons learnt

There is a great need to assess all old and abandoned mines in Namibia that operated in the days when EIAs were not legally required. Mining activities that have caused acid drainage and pollution need to be remediated, especially in populated areas.

In areas where cardinal decisions are required to ensure the safety of human beings, local communities must be informed of the study and results must be explained to them. Governments must also be informed of such studies, to help alleviate the situation of their people.

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