Action TU1208
Civil Engineering Applications
of Ground Penetrating Radar

This lecture is part of the TU1208 Education Pack

Safety issues in Ground-Penetrating Radar and near-surface geophysical prospecting

Raffaele Persico and Lara Pajewski
(r.persico@ibam.cnr.it, lara.pajewski@uniroma1.it)

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Lecture Layout

- Safety and health issues associated to GPR
  1. Introduction
  2. General recommendations
  3. Challenging environmental situations
  4. Risks associated to specific applications
  5. First medical aid
  6. GPR electromagnetic emissions
  7. Safety of equipment and environment

- Conclusions
- References, Biographies & contact details of Authors

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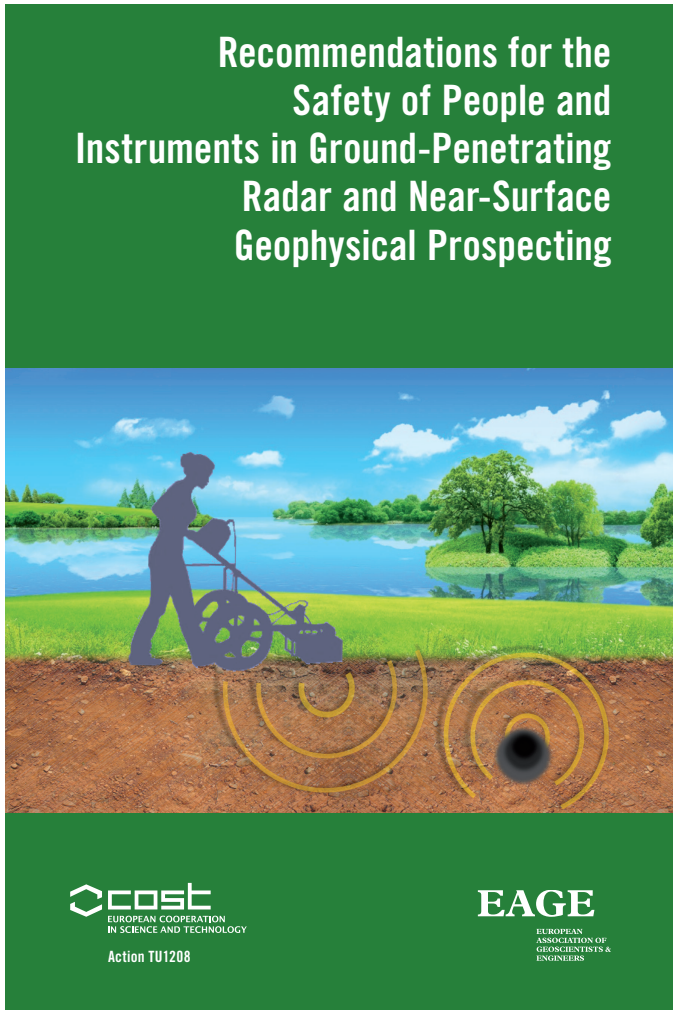
Introduction



- Despite the increasing demand of GPR surveys all over the world, safety matters are rarely considered.
- We believe they are worth being widely debated, in order to increase awareness about risks and precautions in scientists and professionals performing surveys.
- The COST Action TU1208 has made efforts in this sense, resulting in the publication of a book where several practical recommendations are provided for the safety of people and equipment in GPR and NSG prospecting. To the best of our knowledge, this is the first volume on this topic.

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Safety and health issues associated to GPR: 2. General recommendations – some examples

Geophysical prospecting is both a manual and an intellectual work.

People involved in geophysical prospecting need to be adequately prepared before carrying out a survey, in order not to cause hazardous situations for themselves and other people in the crew. They shall never be:

- Under the effect of alcohol or drugs;
- Ill or convalescent;
- Exhausted before starting the activity, for example for not having slept enough.

Any misunderstood sense of duty has to be avoided: if we are not in adequate physical conditions, we cannot contribute to the success of an experimental campaign; conversely, we can become a problem or a risk factor for our colleagues and ourselves.

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Safety and health issues associated to GPR: 2. General Recommendations – some examples

The crew shall always get informed in advance about:

- How to reach the first aid station closest to the place of the measurement campaign;
- Emergency telephone numbers, to be called for medical and police aid;
- Climate and weather forecast in the area where measurements have to be done.

Moreover, the crew shall wear adequate clothes (proper kind of clothes and adequate quantity of clothes), suitable for the foreseen weather conditions and time length of the survey.

At least a member of the crew shall be trained for handling emergency situations and first medical aid. All members of the crew have to be informed about the location and content of the medicine chest.

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Safety and health issues associated to GPR: 2. General Recommendations – some examples

The crew shall be equipped with a medicine chest containing at least the following objects:

- Sterile disposable gloves;
- Visor against squirts;
- 1 L of povidone-iodine at 10%;
- Compresses of sterile gauze
  10 × 10 cm (10) and 18 × 40 cm (2), in single envelopes;
- Disposable sterile coveralls (2);
- Sterile disposable tweezers for medication;
- A package with medium-size elastic mesh;
- A package of absorbent cotton;
- Two packages of adhesive plasters of various size;
- Two rolls of adhesive plaster 2.5 cm wide;
- Scissors;
- Two packages of dry ice, ready for use;
- Two disposable bags for medical garbage;
- A thermometer;
- A blood pressure monitor.

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Safety and health issues associated to GPR:
2. General Recommendations: more in the book

Further general recommendations, as well as recommendations for pregnant women, hygienic and alimentary precautions, suggestions for the organization of a base camp, and more, are found in Chapter 1 of the book.

How to lift heavy objects

How to use a reanimation balloon

Protective glasses

Grass has to be cut and removed before the prospecting

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Safety and health issues associated to GPR: 3. Challenging environmental situations

During geophysical prospecting, the members of the crew can be exposed to challenging environmental situations, for example:

- high or low temperatures,
- rain,
- height over the sea level,
- acoustic noise,
- ultraviolet radiation,
- atmospheric pollution or dusts,
- insects,
- venomous animals,
- detrimental plants…

For each situation, specific cautions can be advised.

In the next slides, a few cases are exposed with some detail.

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Safety and health issues associated to GPR:
3. Some examples: A. High temperatures

In many cases GPR inspections are carried out during summer (for example, in archaeological sites), when the soil is drier and the signal penetration is higher.

In such situations, it is well advised to start the work at dawn and stop at lunch time, possibly devoting the afternoon to data processing activities and avoiding further measurements under the sun. Possible problems are fainting and heatstroke.

Even your instruments, and not 'only' you, may have problems.

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Safety and health issues associated to GPR:
3. Some examples: A. High temperatures

People performing measurements shall wear a hat, or a cap with a visor.

If a naturally shady area is not available, it shall be created by means of an umbrella or a tent.

A portable fridge is advised, but water and drinks have to be at a temperature not colder than 8°C; all beverages shall be without gas and not alcoholic.

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Safety and health issues associated to GPR:
3. Some examples: A. High temperatures

Further recommendations for prospecting at high temperature:

- Drink frequently limited quantities of water or drinks (do not ingest more than 1 L in a unique booze-up);
- Wear light clothes, white and made of cotton or linen, with long trousers and thick shoes, with socks (in order to be protected against snakes, spiders, scorpions, or pricky grass);
- Do an adequate number of short breaks;
- Avoid abundant meals, caffeine and excessive quantities of sugar;
- Avoid touching with bare hands any metallic object;
- Avoid wearing metallic objects such as earrings and necklaces; sometimes even the frames of sunglasses can become very hot;

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Safety and health issues associated to GPR:
3. Some examples: B. Low temperatures

In many cases GPR inspections are carried out in glacial regions, as the layered structure of ice contains important geological information, and also because under the ice there might be well preserved organic remains (e.g., prehistoric human beings, mammoths or other biological remains).

It is advised to start the work when the season allows it and to be accompanied by people that have already had practical experiences of this kind of prospecting. The factors of risk are related not only to temperature but also to possible crevasses, firn, and more.

Possible problems are frostbite and hypothermia.

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Safety and health issues associated to GPR:
3. Some examples: B. Low temperatures

Do it with expert people!

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Safety and health issues associated to GPR:
3. Some examples: B. Low temperatures

People performing measurements shall wear adequate clothes, better if propylene clothes; of course they shall also were a suitable hat, gloves and boots.

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Safety and health issues associated to GPR:
3. Some examples: B. Low temperatures

It is important to have a suitable shelter for the night and it is advised to make use of toilet facilities before going out in the morning.

Pay attention that clothes do not get wet: the thermal isolation is worsened when clothes are not dry.

For men, it is better to shave in the evening, after coming back from the work in the field, rather than in the morning. In this way, the natural substances produced by the skin (which partially protect from the cold) will have the time to reform during the night.

It is important in some cases to be accompanied by local guides capable to evaluate the ice thickness, because ice in some cases can overlay a layer of liquid water.

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Safety and health issues associated to GPR:
3. Some examples: C. Height over the sea level

Prospecting at heights might be necessary because there are several important archaeological sites at 2000 m and beyond, especially in South America and in Tibet. There are also modern mountain resorts were GPR prospecting might be committed, for various reasons.

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Safety and health issues associated to GPR:
3. Some examples: C. Height over the sea level

Beyond the height level of 3000 m the oxygen is reduced on average to 31% of the amount available at sea level, and this can cause problems, especially to people not accustomed to these conditions.

Some discomfort is natural and has to be assumed as physiological, but cautions should be adopted in order to avoid that the unease becomes a severe sickness (mountain sickness, cerebral oedema, pulmonary oedema, …).

The main precaution to adopt is to give to our body appropriate time to get accustomed to the reduced amount of oxygen. In particular:

- Rising from the sea level, the first night should be spent at less than 3000 m.
- Beyond 3000 m, the crew should avoid to ascent more than 500 m per day.
- At 4000 m, the crew should spend two nights at the same height before starting the work or moving forward.

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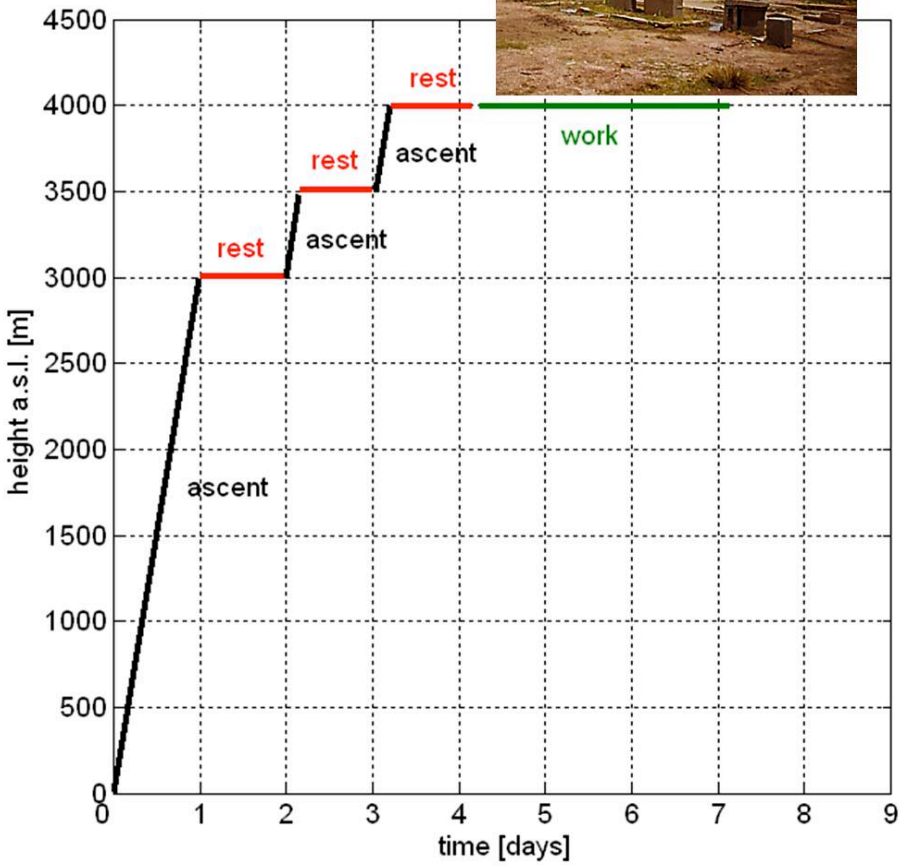
Safety and health issues associated to GPR:
3. Some examples: C. Height over the sea level



Suggested scheme for ascent, rest and work times for a prospecting at 4000 m a.s.l..

Be aware of the possible physiological and pathological problems!

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Safety and health issues associated to GPR: 3. Challenging env. situations: more in the book

Further recommendations for prospecting on lakes, under the rain, in the presence of acoustic noise, ultraviolet radiation, atmospheric pollution or dusts, insects, and more, are found in Chapter 2 of the book.

Some plants that might can cause allergic reactions. From top to bottom: pellitory, reyegrass, olive trees.

Head lamp for prospecting at night

GPR prospecting on a lake (image courtesy of GeoScan Subsurface Surveys)

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Safety and health issues associated to GPR: 4. Risks associated to specific applications

Beyond risk factors related to challenging environmental conditions, it has to be considered that specific applications can involve specific factors of danger, or else they can make general factors of risk particularly important and worth considering.

In Chapter 3 of the book, recommendations are given for GPR demining, bridge and road surveying, sedimentological investigations, archaeological prospecting, mining and tunneling, forensic applications, and borehole inspections. Moreover, some suggestions are given for a safe use of other geophysical techniques, such as induced polarization.

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Safety and health issues associated to GPR: 5. First medical aid

Chapter 4 of the book is devoted to first medical aid. This chapter has the same structure as Chapter 2. In Chapter 2, the purpose was to suggest appropriate behaviour in order to avoid medical problems, whereas the purpose of Chapter 4 is to suggest appropriate behaviour when medical problem happen.

- Problems due to high temperature: heatstroke and fainting
- Problems due to low temperature: hypothermia and frostbite
- Mountain sickness
- Acoustic stress
- Problems due to ultraviolet radiations
- Bites of insects, venomous animals or infected animals
- Contact with venomous plants
- Asthmatic crises
- Wounds and blows …. and more

How to apply a loose bandage

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Safety and health issues associated to GPR: 5. First medical aid

First medical aid is never meant to replace the intervention of a doctor, but in some emergency situations the doctor may be not immediately available. In such cases, it is very important to know what to do and it is even more important to know what not to do, on the basis of the problem at hand and of the symptoms.

Let us remind that the address and phone number of the closest medical presidium shall always be taken in advance, before starting the prospecting, especially when working far from home.

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Safety and health issues associated to GPR: 6. GPR radio emissions

GPR radiates non-ionising electromagnetic waves. Hence, its use requires caution related to the absorption of electromagnetic power by the human body. This is the topic of Chapter 5 of the book.

To the best of our knowledge, there is no comprehensive study specifically related to the radio absorption of energy radiated from GPR systems and its possible short- and long-term effects.

The power density radiated by GPR systems is customarily several orders of magnitude lower than the well-known international limit of 1 mW/cm^2. Usually, power levels radiated by GPR systems are of the order of a few mW as peak power and on the order of a few µW as average power (with the exception of borehole GPR systems, which radiate with antennas inserted under the air–soil interface).

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Safety and health issues associated to GPR: 6. GPR radio emissions

The levels of electromagnetic fields impinging on a GPR operator depend on the system and the surrounding environment.

The energy is essentially radiated in a broadcast direction (again, with the exception of borehole systems), i.e., away from the human operator, which is both a technical need and a legal requirement in EU and the US. Most systems are equipped with shielded antennas: this happens virtually all the times, except for prospecting at low frequency (below 100 MHz) and in borehole applications.

Although quantitative and exhaustive studies on the human absorption of electromagnetic power emitted by GPR systems do not exist, there seem to be no reasons to be excessively worried.

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Safety and health issues associated to GPR: 6. GPR radio emissions

Some measurements were carried out in the framework of COST Action TU1208, which confirm this reassuring claim.

There also are indirect proofs of this claim.

For example, external electromagnetic interference is often suffered by GPR systems: Skilled users are able to recognize tracks of such interference in the data and, when the interference is caused by narrow-band signals, they know how to erase or mitigate it, through suitable filtering. However, we have no notice about televisions, radios, mobile phones, computers, or any other devices perceivably disturbed by GPR prospecting performed nearby.

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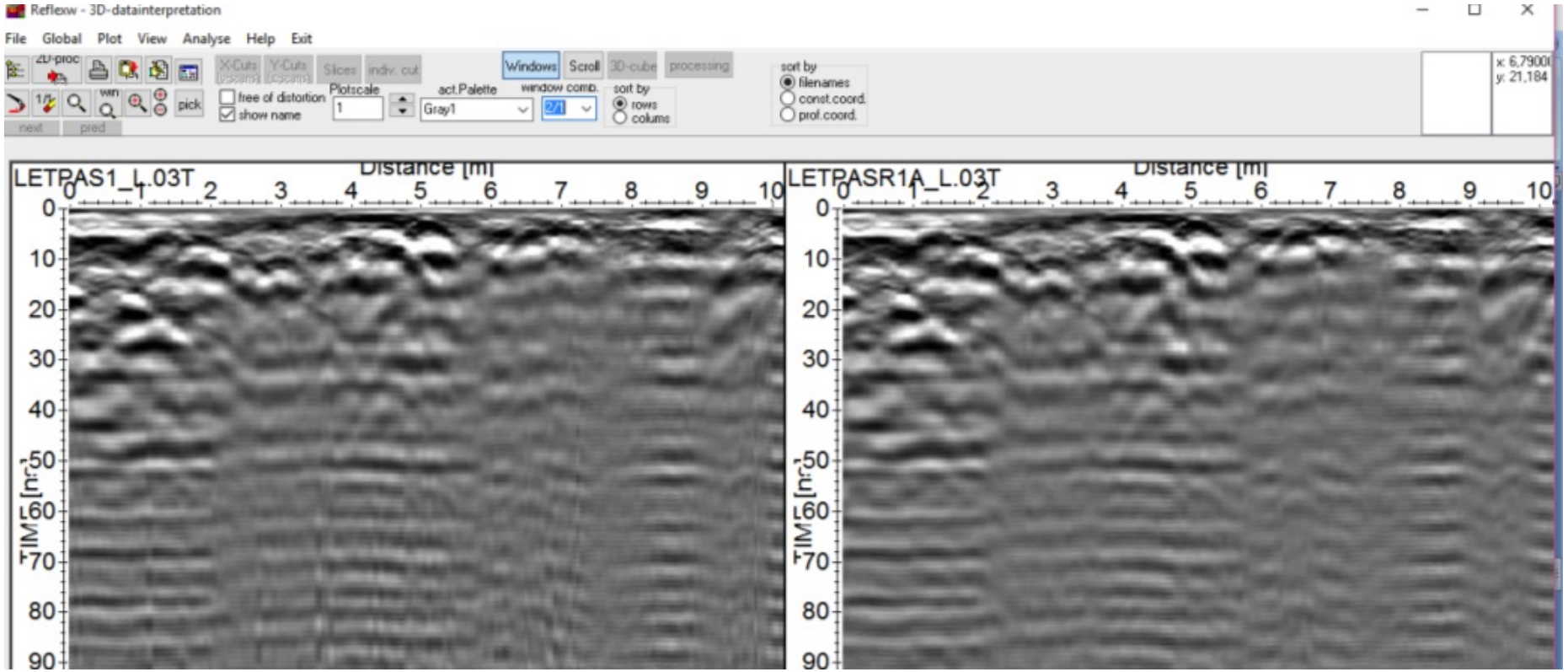
Safety and health issues associated to GPR:
6. GPR radio emissions

Here we show the effects of a moderate interference on a B-Scan, caused by a radio repeater: data on the right are taken along the same line as data on the left, but a suitable hardware has allowed the rejection of the interference.



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Safety and health issues associated to GPR: 6. GPR radio emissions

The main practical suggestion is to avoid pointing a radiating GPR antenna versus any person.

Crew members who are not operating the radar should be as distant as possible.

It is well advised to alternate the human operator driving the GPR periodically during the prospecting, particularly if many hours for several consecutive days have to be spent in the field.

Note that the laptop on which data are visualizza in real time during the prospecting emits microwave radiations when switched on (same as all computers): the power density emitted by the laptop and absorbed by the body of the human operator is generally much higher than the homologous quantity referred to the antennas of the GPR system.

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Safety and health issues associated to GPR: 6. GPR radio emissions

Beyond these practical cautions, it is advised to check that any due guarantee from the manufacturers of the employed instruments is properly documented. Indeed, GPR instruments have to respect specific regulations with regard to the emitted power, as is explained in our book.

Note that the fact that GPR systems are (and have to be) certified, implies that users shall never modify them (for example, with the purpose of improving their performance), as this may drive the system out of the regulation limits, damage it, and make it harmful for the users.

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Safety and health issues associated to GPR:
6. GPR radio emissions

To conclude:

Be aware that there are international regulations on the use and selling of GPR systems

The world technical Authority is the International Telecommunication Union (ITU).
The world regulatory Authority is the World Administrative Radio Conference (WARC)
Both are issues by ONU.

Manufacturers have to respect the standards and regulations in force in the areas where they wish to sell their instruments; they have to provide certifications to the buyers. **Users** have to use certified instruments and have to avoid to do any modification to the instruments.

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Safety and health issues associated to GPR:
6. GPR radio emissions

There are also macro-regional regulations on the use and the selling of GPR systems.

The European technical Authority is the European Telecommunication Standard Institute (ETSI).

The European regulatory Authority is the Electric Communication Committee (ECC)

Both ETSI and ECC are recognised by the European Union.

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Safety and health issues associated to GPR:
6. GPR radio emissions

Macro-regional regulations outside Europe:

ETSI standard are often recognised in African countries and Russia.

In the American continent the recognised Authority is the Federal Communication Commission (FCC).

We do not have notice of other structures recognised in other regions of the planet.

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Safety and health issues associated to GPR: 7. Safety of equipment and environment

Chapter 6 of the book is devoted to suggestions for a **correct use** of GPR equipment during surveys.

Examples:
If the laptop where data are stored is not inserted into a rigid structure, than it shall be adequately fastened, in order to avoid its fall during the prospecting.
Equipment bags and boxes shall not be forgotten open.
Batteries shall never be opened or damaged, because they contain toxic and polluting substances.
Equipment shall never be used beyond the allowed range of temperature, which is customarily specified in the data sheets.

In the same chapter, suggestions for a **safe transportation** of GPR equipment are given and rules for transportation abroad (e.g., ATA Carnet).

Finally, recommendations to **respect the surrounding environment and fauna** are given.

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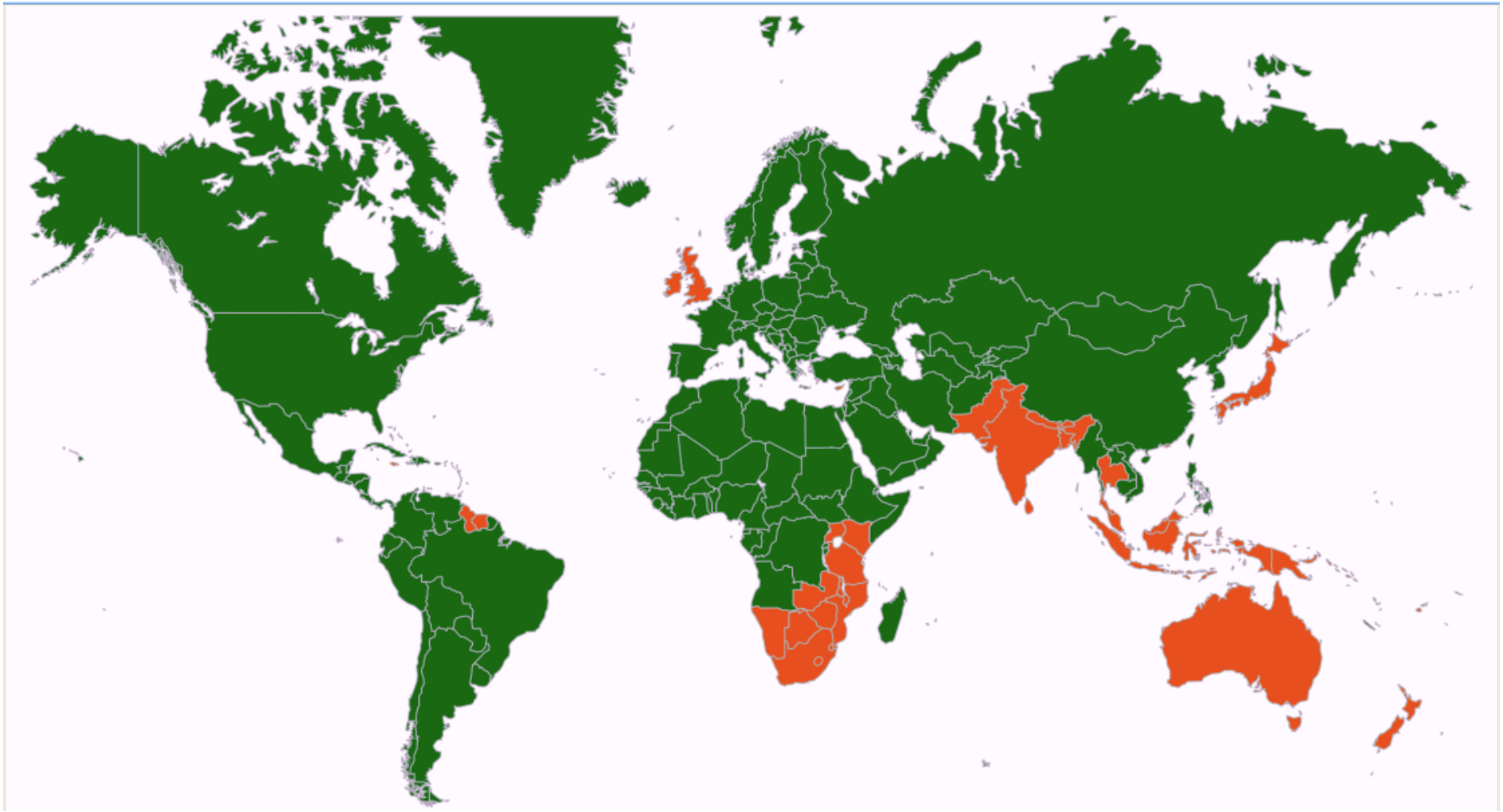
Safety and health issues associated to GPR:
7. Equipment & environment: Driving abroad



Safety and health issues associated to GPR: 7. Equipment & environment

Transporting instruments abroad

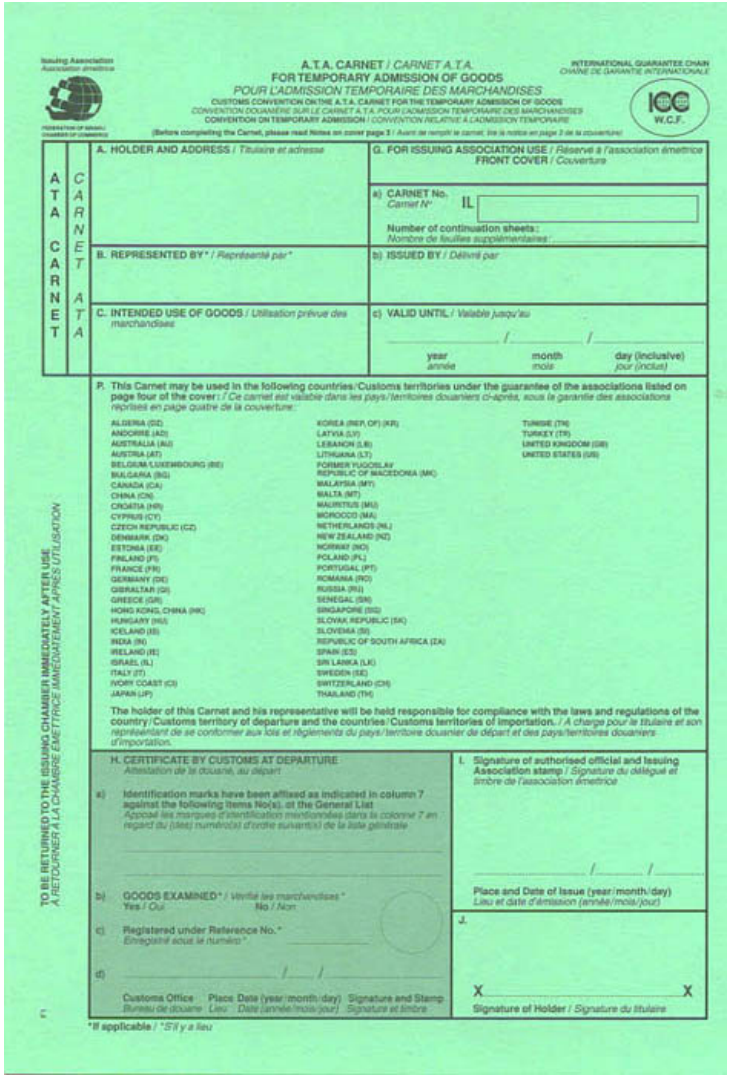
The best is: travel by car and bring them with you

Else, send them with an expert courier…

..or rent them on site

Safety and health issues associated to GPR: 7. Equipment & environment

Carnet ATA



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Conclusions

In this lecture, recommendations were given for the safety of people and instruments during Ground-Penetrating Radar (GPR) inspections. More information on this topic is found in the TU1208 book:

R. Persico, A. Provenzano, C. Trela, M. Sato, K. Takahashi, S. Arcone, S. Koppenjan, L. Stolarczyk, E. C. Utsi, S. Ebihara, K. Wada, E. Pettinelli, L. Pajewski,
***Recommendations for the Safety of People and Instruments in Ground-Penetrating Radar and Near-Surface Geophysical Prospecting**,*
European Association of Geophysicists and Engineers, 2015.

We are aware that this topic is not, strictly-speaking, scientific. However, safety is a serious issue and it is seldom considered in GPR and near-surface geophysical prospecting. Therefore, we believe that our recommendations are worth being disseminated, in order to increase awareness of the operators and stimulate discussions.

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Conclusions

We do not know of people permanently injured or dead during GPR prospecting, however we know that various accidents happened in the past. The work carried out by the COST Action TU1208 takes into account the personal experience of several professionals and scientists who have been working with GPR for many years and have directly faced dangerous or potentially dangerous situations, or else they have been informed of such situations by reliable colleagues. Hence, all provided recommendations are based on real facts or events.

In the near future, we plan to extend the volume and publish a second edition. If somebody is interested in contributing, we will be very happy to provide her/him with a complimentary copy of the book!

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References

[1] R. Persico, A. Provenzano, C. Trela, M. Sato, K. Takahashi, S. Arcone, S. Koppenjan, L. G. Stolarczyk, E. C. Utsi, S. Ebihara, K. Wada, E. Pettinelli, L. Pajewski, "Recommendations for the Safety of People and Instruments in Ground- Penetrating Radar and Near-surface Geophysical Prospecting", EAGE Publications bv, June 2015, ISBN 978-94-628-2162-0.

A deliverable of COST Action TU1208, providing recommendations for a safe prospecting, suggestions for safety equipment to be brought in the field, specific advice for experimental campaigns carried out in challenging situations. Part of the volume is devoted to resuming the EU regulations for GPR manufacturers and end-users; risks associated to EM emissions are also discussed. The book includes a first medical aid guide and suggestions for a correct use and safe transport of equipment.

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Authors

Dr Raffaele Persico (r.persico@ibam.cnr.it) is a Researcher at the Institute for Archaeological and Monumental Heritage IBAM-CNR, Lecce, Italy. He was the Chair of the 13th International Conference on GPR. He is the President of "Associazione Italiana del Georadar" and a WG Member of COST Action TU1208. His interests in the field of the GPR range from inversion algorithms to innovative systems with special emphasis on applications on cultural heritage and monuments of historical interest.

Dr. Lara Pajewski (lara.pajewski@uniroma1.it), Chair of COST Action TU1208 "Civil engineering applications of Ground Penetrating Radar," is a Professor of Electromagnetic Fields in Sapienza University of Rome, Dep. of Information Engineering, Electronics and Telecommunications, Rome, Italy. She is an electronic engineer with a PhD in applied electromagnetics and electrophysics sciences. She is an expert in GPR and its applications, electromagnetic modelling of complex scenarios, design and characterisation of antennas. For more info, please visit GPRadar.eu/people/chair-of-the-action.html

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