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RISK ASSESSMENT OF CONTAMINATED INDUSTRIAL SITES – THE RESPONSIBILITY OF GEOSCIENTISTS

Abstract*. Incorrect risk assessments in selected reports show that there are grave consequences if a staff without sufficient geoscientific knowledge is evaluating the risk of contaminated industrial sites. The results move within a tense relationship built up by contradictory financial, administrative and ecological conditions. Depending on the dominant factor, investigations at polluted sites and their practical conclusions sometimes vary between ignorance of actual hazardous situations and an overestimation of observed subsoil and groundwater contaminations. However, it is the immanent function of geoscientists and their responsibility to recognize the concrete environmental state of running or former industrial factories and sites, to predict the future development, to estimate all consequences for important goods of public right and to recommend proper and reasonable conclusions and measures. This task can be done unbiased only by geoscientists because of their unique education. Only they are able to study and estimate systematically and all-embracing subsoil and (ground)water pollutions and effects on the environment. Resulting conclusions should be made in co-operation with juridical and financial experts, technical engineers and competent representatives of authorities having jurisdiction.*

Critical Analysis of Selected Professional Reports

Formerly or at present used industrial sites were investigated to determine the financial expenditure that would be required to eliminate dangerous contaminations. In general, the resulting cost-benefit-analysis is based on factors like (1) kind, vertical and horizontal extension and degree of pollution; (2) type of subsoil, groundwater und surface water parameters and exploitation; (3) in situ and neighboring land use; (4) exposition of priority goods of public right like human healthy, animals and plants, water etc.; (5) juridical regulations and administrative restrictions; (6) corresponding remediation measures and (7) last but not least available financial means. It is the job of environmental experts to research all important factors unbiased and to draw correct conclusions.

A critical view on selected professional reports shows that there are sometimes unsatisfactory results based on insufficient inquiry and estimation of existing contaminations within a concrete complex situation. Some examples may illustrate these inadequacies.

Example no. 1. Samples of the subsoil of a chemical factory were polluted by considerable amounts of the heavy metals cadmium, zinc, quicksilver, and lead. Cadmium concentrations >10 mg/kg were found in 20 of about 150 samples. The reporter required expensive remediation measures to protect soil and groundwater against an impact of these dangerous chemical elements. He did not consider that no one of several groundwater observation drills showed any loading of heavy metals. The factory never dealt with metals. A later correction of the results proved that the subsoil was filled up partly with glass and ceramic slag to stabilize the foundation nearly 100 years ago (Fig. 1). At that time, ceramics colored with metallic salts were produced in the studied area. The heavy metals form now absolutely insoluble silicates; they never can impact ground or surface water and they are harmless. The reporter simply did not think about that all samples were chemically solved with aqua regia, an aggressive mixture of concentrated hydrochloric acid and nitric acid, unknown in the nature. And the chemist had analyzed the obtained solution. Only the revision lead to the result that there is not any hazardous occurrence of soluble and mobile toxic metals (THIERGÄRTNER, 1997).

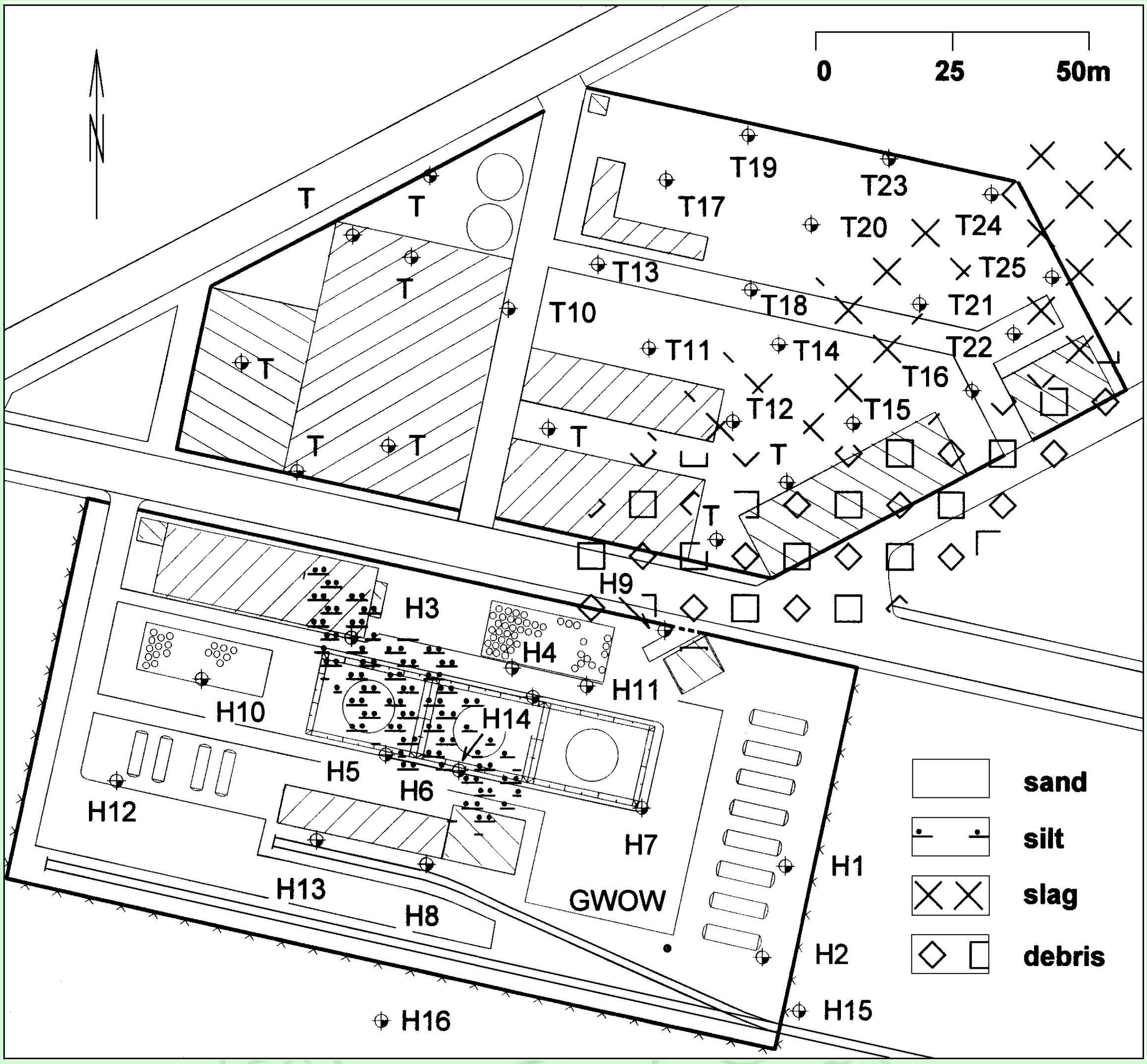

Fig. 1. Insufficient consideration and interpretation of different subsoil substrate.

Example no. 2. Another enterprise produces machines and engines. It is built on a Holocene complex of valley sand and gravel and the groundwater table is near to the surface. 19 gauge wells have been installed, sampled and analyzed with respect to organic toxic and carcinogen substances, among them also polycyclic aromatic hydrocarbons (PAH). One of the observation wells showed an unacceptably high concentration of long-chain PAH which was confirmed by a control sample. Remarkable contents of PAH were not detected in the remaining wells. The reporter created a map of the propagation of PAH concentration values in groundwater applying the computerized kriging algorithm. The map shows more or less concentric curves of decreasing concentrations of PAH around the polluted well. It was recommended to excavate subsoil within a certain inner circle to avoid further dangerous situations – a costly remediation measure. A pollution caused by volatile chlorinated hydrocarbons (VCHC) which are considerably soluble in groundwater has been mapped similarly at the same site (Figs. 2 and 3).

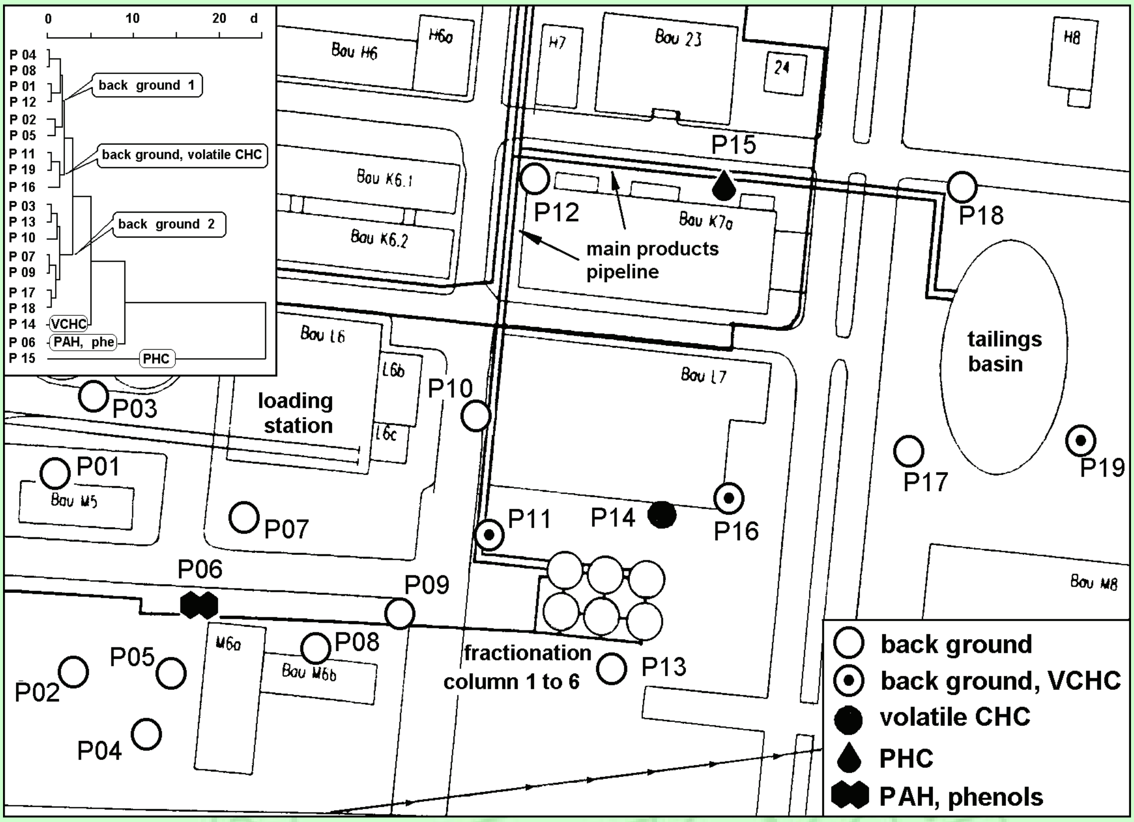

Fig. 2. Hot spots at an industrial site classified by cluster analysis; cf. Fig. 3.

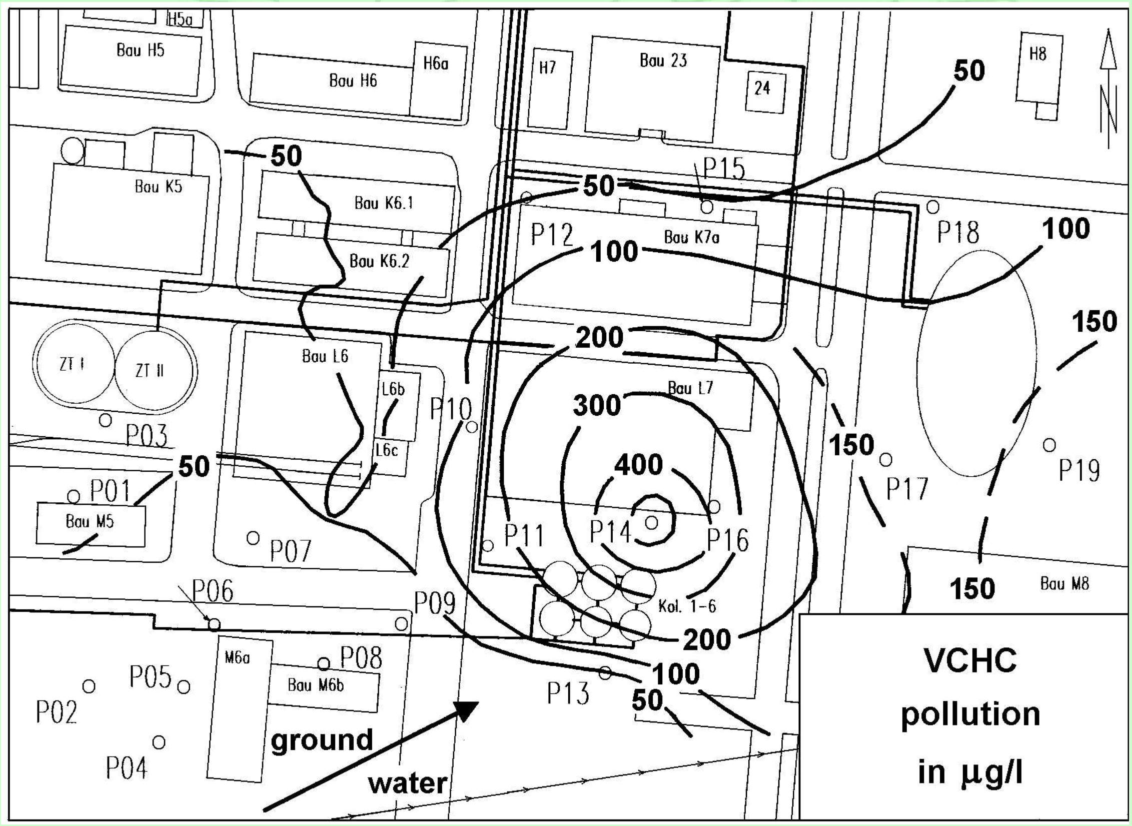

Fig. 3. Incorrect extension of the punctual contamination observed in well no. P 14.

But three important aspects were neglected: first, the very low solubility of long-chain PAH in water; second, that PAH does not play any role in enterprises like the plant in question and that the impact was caused more than a century ago by a punctual deposition of tar-oil bearing residues from a gas generator facility (so, it was sufficient to limit the subsoil excavation to the actual impacted point as a precaution); and third, that the formal application of the mathematical kriging model without regard to the groundwater flow direction leads to apparent pollution plumes for PAH and VCHC also against the groundwater flow (THIERGÄRTNER, 1995).

Example no. 3 reviews a decision according to a contamination caused by arsenic compounds: an industrial site near the river Spree in Berlin was punctually polluted by arsenic compounds. The sandy subsoil in which an unconfined aquifer occurs showed at several points up to 65 mg As/kg dry substance. The measured concentrations were compared with values taken from several orienting lists. Thus the German Decree on drinking-water (TrinkwV, 2001) allowed at that time maximum 10 µg As/l water. The Berlin list (BL, 1996) contains an orienting dangerous standard value of 30 mg As/kg for sand in the ice-marginal valley and the Netherlands list (NL, 1991) included 55 mg As/kg as remediation value (Table 1). Based on the listed values, the reporter recommended to introduce clean-up measures to extract the pollution. However, several points should be inspected critically: The contamination is not area-covering but occurs only at selected points; this can be explained by a local loss of As-bearing material during loading processes. The quoted Decree on drinking-water was made for water, especially for the quality of drinking water produced by German water works and never for the quality of an aquifer respectively surrounding soil. Finally, upper soil in subareas in the German highlands like the Saxon Erzgebirge shows regional CLARKE values of more than 50 mg As/kg (natural background values: RANK & KARDEL, 2003) due to the weathering of mainly arsenopyritic veins (SLfUG, 1996).

Table 1. Concentration of arsenic in soil, values in mg/ kg dry substance.

Source	Explanation	Concentration of As
TrinkwV, 2001	maximum standard value	[10 µg/ l water]
NL, 1991	maximum standard value	55
BBodSchV, 1999	test value for remediation or detailed exploring investigation	50
BL, 1996	critical test value; sandy subsoil in the ice-marginal valley	30
RANK & KARDEL, 2003	natural geogene background depending on underlying substrate	8 … 78

The examples could be continued. It is remarkable that many reports tend to overestimate ecological hazards or at least an environmental danger. There are several reasons for insufficient research, risk assessment and final recommendations: inadequate knowledge about pollutants, their attributes and their behavior within a geological milieu; formal application of standard values made for a first orientation mainly in less specialized authorities; extreme ecological ideas about our environment without regard to feasibility and economic reality; unsuitability of means to answer to observed contaminations; stress made by authorities, by the owners of industrial sites, by potential costumers, by sanitation industries or by the engineering offices waiting for new orders. These are all “human factors”. But the risk assessment at contaminated industrial sites can and should be influenced towards more appropriate environmental estimations and conclusions. This problem directly leads to some ethic questions.

Environmental Risk Assessment

An up-to-date environmental legislation is suitable to prevent or at least to minimize pollutions and ecocides. The industrial development during the last 200 years, however, has lead to considerable chemical and radioactive contaminations of subsoil, surface water and groundwater in numerous countries. Concerning sites are to be investigated at the state of the art. This includes (1) the scientific and technical background, (2) knowledge and application of legal regularities, (3) a reasonable and fair understanding of the relations between ecological requirements and economical potential and (4) an independent position of investigation and investigator.

A proper investigation of contaminated industrial sites is similar to the exploration of a mineral deposit. It involves steps like preliminary historical studies; adequate sampling; record of the surface and groundwater, subsoil and surface situation in three dimensional space; detection, detailed description, quantitative determination and mapping of possible pollutions; scientific prediction of the future behavior like gas emission, dilution, decomposition, interaction with other contaminants, local fixation or natural attenuation of contaminations; search for a possible continuing impact and possible effects on neighbored real estates; study of former, recent and planned future land use etc.

Unlike a geological mineral deposit prospection, regulations given by the legislator determine to a high degree the object of environmental investigations at contaminated sites. In modern states, there are laws and orders to protect human life and healthy, animals and plants, groundwater, surface water, soil and air. Laws and decrees may define upper limits for harmless concentrations of toxic, carcinogen or radioactive pollutions in different media distinguished by several types of land use as sensible exploitation for child’s playgrounds or senior’s homes, groundwater production, residential areas, mixed zones, industrial sites. Admissible maximum loadings in subsoil and groundwater are also depending on the local and regional geological setting, lithological type of subsoil, depth of the aquifer and its degree of protection against any polluting impact, fracture-tectonic situation and so on. The German Act on Soil Protection (BBodSchG, 1998) and the subordinate Federal Decree on Soil Protection and Subsoil Contamination Caused in the Past (BBodSchV, 1999) exemplary take into consideration that different modes to use land and different types of subsoil require and allow specific maximum values to start detailed investigations and clean-up measures at contaminated sites. Such approach had certainly influenced the restrictive decision regarding the mentioned example no. 3.

The relationship between ecological ideas and the economic reality is a very sensible problem. Rather extreme conceptions try to reconstruct more or less pre-industrial conditions. Such ideas are honorably but – with the due respect – unrealistically ones. We know that nearly all areas of our planet Earth are irreversibly influenced by mankind. It seems to be more appropriate to apply available means to avoid strictly any further contamination of our environment instead to repair older defects. On the other hand, there are numerous actually hazardous contaminations in subsoil and groundwater, first of all, at industrial sites. They have to be treated to prevent dangerous situations. They cannot be ignored and they require more or less intensive remediation measures. Frequently, less or not polluted subareas are adjacent to significantly contaminated parts, sometimes in a close interbedding. An exact inventory and a distinguishing estimation are inalienable. The development of an adequate scheme of sampling can be the first step to model the situation unbiased. A not less essential factor is the use of a gray value scale when estimating the existing situation. There are many imaginable conclusions between ignorance and total elimination of a pollution. Sometimes, it is sufficient to believe in the power of natural attenuation or to introduce a monitoring of natural attenuation. In other cases, soil can be simply sealed or the migration of hazardous substances can be stopped breaking the zone of capillarity. Aquifers can be cleaned up by pumping, adsorption at active coal and re-infiltration. Special cases require a complete excavation and treatment of subsoil, etc. The range of proved measures is wide and growing. They differ in effect and in the necessary expenditures and should be selected to succeed and to minimize means. An application of orienting standard values to evaluate an industrial contamination may be respectable for an administration without geoscientific know how. The geoscientist is asked to treat each case of subsoil pollution individually – considering all given facts, local features, spatially differentiated contamination, former and future land use etc. and to base his recommendation for decisions on the real situation as a whole.

Scientifically based precise recognition and objective assessment of contaminations at industrial sites are soluble tasks in fact. An important presupposition, however, is the independence of investigation. Owners of contaminated industrial sites could try to revalorize their property, e. g. to change it to a residential area. Such ideas require more intensive remediation measures but they exceed the normal risk assessment and need special means. Or it could be tried to play down the ecological risk to minimize costs. Or interested sides could use the opportunity of a running risk assessment to require more than a re-vitalization of sites. There are no few imaginable, mainly economical reasons to influence the tendency of risk evaluations. Owners of devastated sites, public authorities, remedial industries and engineering offices pursue not seldom contrary targets. The obligation to prevent any danger for important goods of public right proceeding from subsoil pollutions, however, is a basic principle of risk assessments at contaminated industrial sites. All recommended measures derived from the existing situation – (monitored) natural attenuation up to a punctual or total cleaning-up – have to serve this principle and should be appropriate to it. A “less” would be negligent, a “more” would only help to revalorize the site for its owner. The weighting of benefit and protection interests is one of the most difficult problems at risk assessments.

The Responsibility of Geoscientists

As mentioned above, it is obvious that basic problems of a correct investigation of contaminated industrial sites are similar to the exploration and evaluation of mineral deposits. They are problems of geosciences.

Only a geoscientific, first of all geochemical and hydrogeological, correct inventory, representation, estimation and conclusion is able to make objective characteristics of subsoil and groundwater pollutions. Geoscientific ideas and tools move like the famous red thread through all phases of environmental studies. Neglecting them, it is impossible to derive balanced suggestions with regard to the further proceeding at contaminated industrial sites, to protect our nature against permanent damages but also to avoid unjustified expenditures.

The consideration of such important problems as existing groundwater and surface water conditions related to the site, regional CLARKE values compared with the measured pollution, the ability of pollutants to migrate and their real mobilization, interactions between pollutants and subsoil up to fixation within crystal lattices, the natural attenuation of contaminants etc. can be guarantied only by best educated geoscientists working with high sophisticated investigation techniques. Environmental analyses which are not based on geosciences are prior insufficient and do not produce optimal results.

It is only the geoscientist who knows the different types of sampling in optimized grids combined with hot spots, in groundwater or surface water upstream and downstream, who can distinguish between natural contents of chemical substances in subsoil, ubiquitous loading of long-term used industrial areas and limit value crossing contaminations etc.

The responsibility of geoscientists regarding the risk assessment of contaminated industrial sites is directly resulting from the geoscientific character of essential working procedures concerned with this problem. Geoscientists are predestinated to prepare decisive recommendations about the whether, way, extension and continuance of measures to remediate and protect important environmental mediums against any contamination. They are the competent experts to develop proper decisions about the treatment of polluted sites within the tense relationship between environment, law and finances. It goes without saying that the competent authorities have to decide the further proceeding but this decision should be based on geologically founded investigation results; it is not realistic to expect that (in general) public administrations are equipped with the required special knowledge. Geoscientists must not leave this problem to less or not geoscientifically educated staffs.

Important consequences are as follows: (1) Geoscientists should, first of all, realize this situation and, at the time, challenge. They should be responsible and must not cede this field to another, less suitable staffs. (2) Their responsibility includes a correct way how to deal with geoscientific facts and recognitions, lawful ecological requirements, interests of owners, neighbors, administrations and finances in a well-poised field. (3) A special requirement is that geoscientists do not subordinate scientific results and conclusions to exclusively economical interests. (4) It is necessary to understand the risk assessment of contaminated industrial sites as a very complex problem which cannot be solved by geological tools alone. So the responsibility of involved geoscientists includes the requirement to specialize in the field of ecology and permanently to deepen his education, knowledge, faculties and experience – not only in geosciences but also in jurisdiction, economy and related fields. (5) This aspect includes also to work according to the state of the art, to apply most modern methods of investigation, analysis and representation, and to organize a constructive co-operation with experts in neighbored scientific fields.

Making use of these problems and responsibility, it is possible to involve the legal skeleton conditions at the time, legitimate interests regarding neighboring real estates, ideas about the further exploitation and commercialization and the economical proportionality of ecological measures as well into the ecological risk assessment based on geoscientific facts. Errors as shown above can and have to be avoided. Every geoscientist working according to the rules of profession given by the Federation of European Geologists (Code, 1986) knows this ethic standard and will not have problems to meet the obligations if he evaluates contaminated industrial sites.

Conclusions

The risk assessment of contaminated industrial sites should be carried out based on mainly geoscientific ideas and high sophisticated methods. Every case is to be proved and estimated individually. Concluding measures should recommend to remedy as possible least but as necessary much. Geoscientists are responsible to solve these problems at a high scientific level and not influenced by contradictory factors.

Geoscientific education, knowledge and experience are essential supports to guarantee unbiased field observations, analytical work, description and conclusions. Owners of relevant sites, public authorities, administrations and engineering offices are well advised to add geoscientists to their investigating staffs and to appoint them responsibly with the environmental risk assessment – in co-operation with engineers, lawyers and economists.

Geoscientists should keep in mind that they are predestinated to make risk assessments at contaminated sites first to guarantee objective, unbiased estimations and second – last but not least – to prevent an important field of their jobs.

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