ENVIRONMENTAL CONTAMINATION ON FORMER MILITARY SITES AND HAZARDS TO THE DRINKING WATER IN GERMANY

Inventory and health risk assessement of environmental contaminants

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Abstract:

An assessment concept was developed accordingly to the claims of "*Vorsorge*" (precaution) of the drinking water hygiene, which authorise a prospective evaluation of potential environmental contamination. The problematic is represented by the example of military contaminated sites in Germany and generalised by an adequate and extensive system of assessment for soils and waters. Over the description of substance properties of the environmental contaminants, values of substance characteristics (SC-Values) will be calculated. The combination of different values of substance characteristics shows a potential exposition and health risk over the drinking water path. The identification of hazards is presented, in a second step, with explicit health related guidance values (GV) and in form of measure values (short term health related guidance values GV_{SE})[1] in the context of human toxicological assessments. Another approach is the calculation of permissible bearable maximum concentrations (BMC) through an aqua toxicological evaluation. With these two concentrations - the human-tox and the aqua-tox derivated - values, one can decide on the fact whether the chemical quality of contaminated drinking water is (still) healthy safe or whether the aquatic biocoenosis could be adverse influenced.

Key words:

Military contaminated sites, drinking water, environmental contamination, human toxicity, aqua toxicity, ecological toxicity, health assessment, biochemical degradability, mobility.

1. Basics

The exposition of humans opposite chemical substances released through anthropogenic influence based on the steady growing chemical production and the decades long use of these substances, despite of the strengthened contrary efforts[2], must be classified with increase (INC

[1] SE: Short Term Exposure

[2] e.g. the ban covered substances of the POP convention (as "…according to international binding law instrument for the implementation of international measures regarding to certain persistent organic parameter." - POP- Convention v. 10.12.2000 in Johannesburg; cp. Umwelt Nr. 2 /2001, BMU, Berlin)

2000). These environmental chemicals are to be differentiate into such, regarding their origin area, which was brought deliberately and use-oriented into the environment, e.g. plants treatment means (particularly herbicides, insecticides and fungicides) as well as antibiotics (e.g. penicillin, chloroamphenicol) and into such, which arrived or still arrive unintentional, careless or from unsatisfactory *Vorsorge* (precaution = "pre-care") (e.g. polycyclic aromatic hydrocarbons and dioxins) into the environment. Thereby, in the past, chemical contaminated site had represented a considerable part in these environmental contaminations. The *Vorsorgeprinzip* (precautions or *pre-care* principle) is applied during the assessment of the dangerousness of substances of the first mentioned origin area. Environment relevant former contaminated sites can only be solved through the *Nachsorge* (aftercare). Thereby, a particularly possible attention should be paid to potential and real contaminations regarding to the food chain and the drinking water resources.

The transition of the contaminated site substances of the environment media water, soil and air into the human food chain signified then, in particular, a health risk, if the substances are toxic and biochemical stable in the environment or if their metabolites are evaluated more critically as the original substances. Therefore, toxicity and degradability form the key criteria of this risk assessment.

The different objectives of *pre-care* and aftercare become particularly clear in the military activities: In peace times, the precaution principle is also apply in many regards at the military (compare e.g. "minimisation commandment" in the German drinking water regulation), unless perhaps without restrictions. Military conflicts are always based on their destructives aims and associated with the release of dangerous and toxic substances that concern all environmental compartments including ground and raw waters. Apart from a possible direct immediate side-effect of sabotage toxins, weapons and explosives at human's military activities lead among other also to a direct and indirect endangering of the drinking water resources. Dangers for humans and nature after military practices or warlike conflicts could only be minimised in the way of an intensive aftercare remains through rehabilitation or restoration measures.

The statement of possible health dangers through adverse effects of the substances takes place via scientific methods and assessment criteria. These should consider knowledge gabs and show the correlation between exposition and effect of pollutants in the environmental media and drinking water. In this article, the danger criteria for humans, especially for the drinking water path, are systematised and the congruence is proved between legal normative standards - and deduced measures for the environmental media (soils, ground water and drinking water) - and management of risk on scientific basis. The execution deficit of measures up to now will get clear from the hygienic quality requirements in drinking water and the divergence between "pre-care claim" and "aftercare success" in danger defence.

2. Conclusion to the Hazard Statement of Military Contaminated Sites in the Drinking Water Supply in the new Federal *Länder* of Germany

The massive potential groundwater pollution from military operations became apparent and subject of scientific research in the early 1990s, in the wake of the *détente* process between East and West. This scarcely confirmed the often-expressed hope that many of the military chemicals, which are classified as dangerous, would quickly be degraded in soil to non-hazardous concentrations (Mulisch et al 1999 a, b).

In the intention to obtain a representative statement on consequences of the military contaminated sites on the drinking water supply in Germany, were stood researches in the surrounding field of former WGT-areas (WGT = west's group of the troops of the former Soviet army) in the central point of the assessment of health risk through the drinking water

contamination. Supplementary former NVA-areas (= *Nationale Volksarmee*, German troops of the national people army) in the free state of Saxony were included into these investigations (Mulisch and Schorling,1997; Mulisch 1998).

2.1 INVENTORY

The WGT-areas were isolated for decades from the public. Activities, material and many accompanying factors like e.g. potential pollutant and permanence effect were unknown. The assessment of the respective hazard potential for drinking water was significantly complicated through it, which was usually missing accurate substance statements.

Basics of the inventory are examinations of the Federal Ministry for Environment, Nature Protection and Reactor Security respectively, executed by the Federal Agency for Environment, which covering altogether 1,026 areas (BMU, 1995). Beyond this supplementary statements from the countries, the Federal Financial Administration and the Federal Armed Forces (Bundeswehr) and Researches of the Health Authorities were taken up to the data acquisition, particularly of special parameters, like chlorinated hydrocarbons substance and explosives (FKST, 1994). Through the definition of different types of utility areas, it is possible to conclude on suspicion and priority contaminants that were proved in suspect cases by health authorities over a corresponding analytics by soil and water samples (Thieme et al, 1994).

In the result of these studies altogether 33,750 suspicion contaminated site areas (SCSA = Altlastverdachtsflächen) were determined. 32 % of those (= 11,079 SCSA) were classified as an endangered ground water. From these, 53.8 % (= 5,960 SCSA) is located inside drinking water protected areas.

The results represented here, refer to a subset of 929 of these WGT-areas, which were carried out in the frame of BMU's environmental research plan until the year 1999. In doing so, suspicion contaminated site areas (SCSA) were detected and documented in 140 military training sites, 406 garrisons, 80 airports, 147 camps and bunkers as well as 42 large fuel depots. These environmental relevant SCSA form a contaminated total area of appreciatively 5,700 ha.

Focuses of environmental pollutions are the utility areas

- fuel depots, petrol stations, airports, wash and maintenance ramps,
- munitions and arsenals, shooting facilities, explosive places and fire places,
- burials and shifted areas,
- defective canalisations as well as sewage plants,
- unordered waste deposits and scrap places.

Without meaning in the sense of the aim position 29,382 SCSA are registered with waste mineral origin. Only in some cases, 4,715 SCSA with vegetable wastes as well as the 6,165 with settlement wastes are of relevance of ground and drinking water. The studies, highlighted on the basis of few established analyses, had shown that also "radioactive wastes" are not significant for the drinking water supply.

On the other hand, the "wild waste deposits" are evaluated as critical. Altogether about 465,000 tons of material of all kind of wastes, inclusive munitions rests, were illegally disposed on „shifted and burials areas". Large insecurities exist particularly in connection with shifted and burial areas inside drinking water protected areas, because specific evidences referring to their composition were missing and it is no longer possible to get this information after the departure of the WGT.

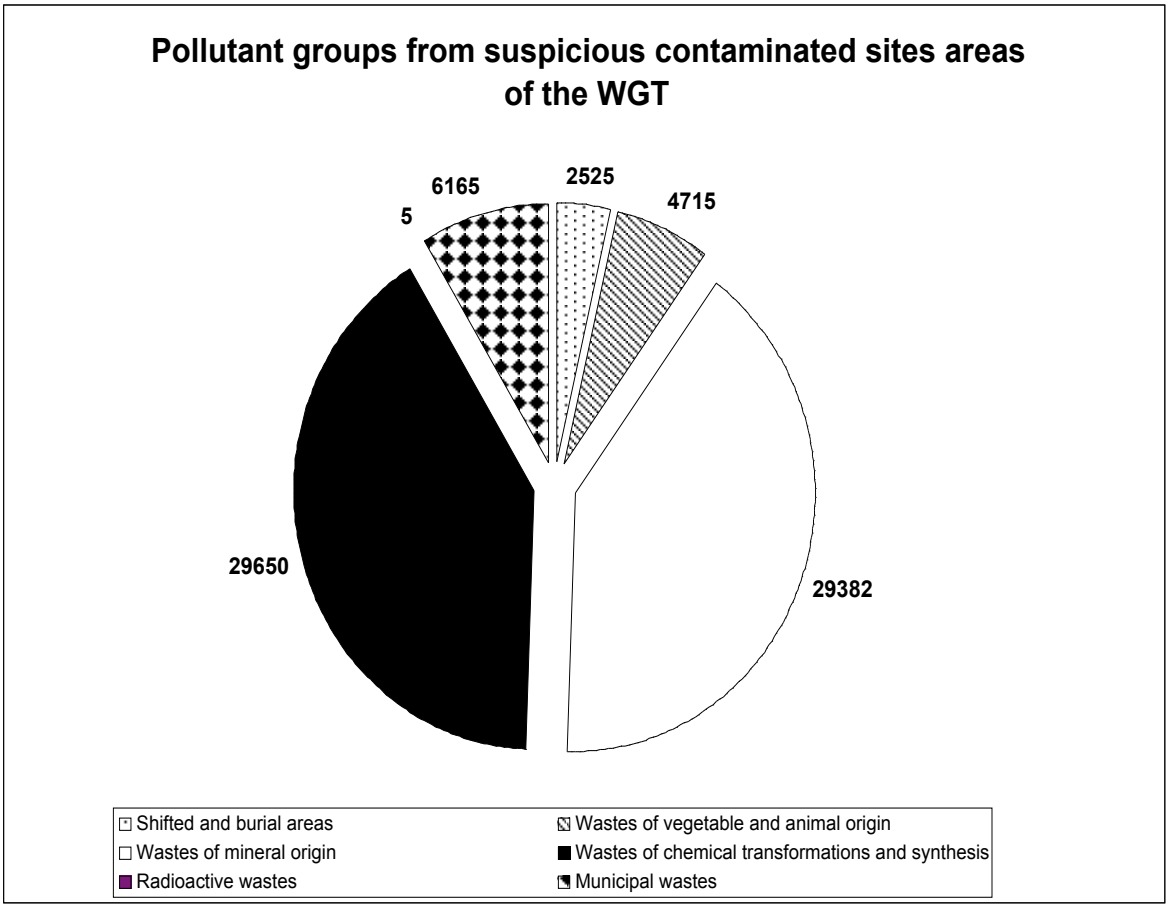

FIGURE 1. Pollutant Groups from Suspicion Contaminated Sites Areas WGT-areas

The overview in Figure 1 shows the determined materials on the SCSA according to the generic terms defined in the WGT program: shifted areas, burials, wastes of mineral origin, radioactive wastes, wastes of vegetable and animal origin, wastes of chemical transformation and synthesis products as well as municipal wastes.

The pollutants, which are combined under the generic term "wastes chemical transformation and synthesis chemical products", represent, beside the munitions residues, the main group of the drinking water supply endangering material. The materials or groups of materials designated here are classified in the Table 1 as well as in Figure 2 over the environmental relevant quantities in tons (t).

TABLE 1. Pollutant Groups on SCSA and their relative Parts on WGT-properties

Code Nr.	Description	Part SCSA [%]	Estimated Relative Mass [%]
5.1	Oxides, hydroxides, salts	2%	5%
5.2	Acids alkaline solutions, concentrates	2%	<1%
5.3	Pesticides and pharmaceutical articles	1%	1%
5.4	Mineral oil product	51%	71%
5.5	Organic solvents, paints, lacquers, adhesives, mastics, resins	11%	1%
5.7	Plastic and rubber wastes	19%	11%

Code Nr.	Description	Part SCSA [%]	Estimated Relative Mass [%]
5.8	Textile wastes	4%	<1%
5.9	Other wastes of chemical production	10%	10%

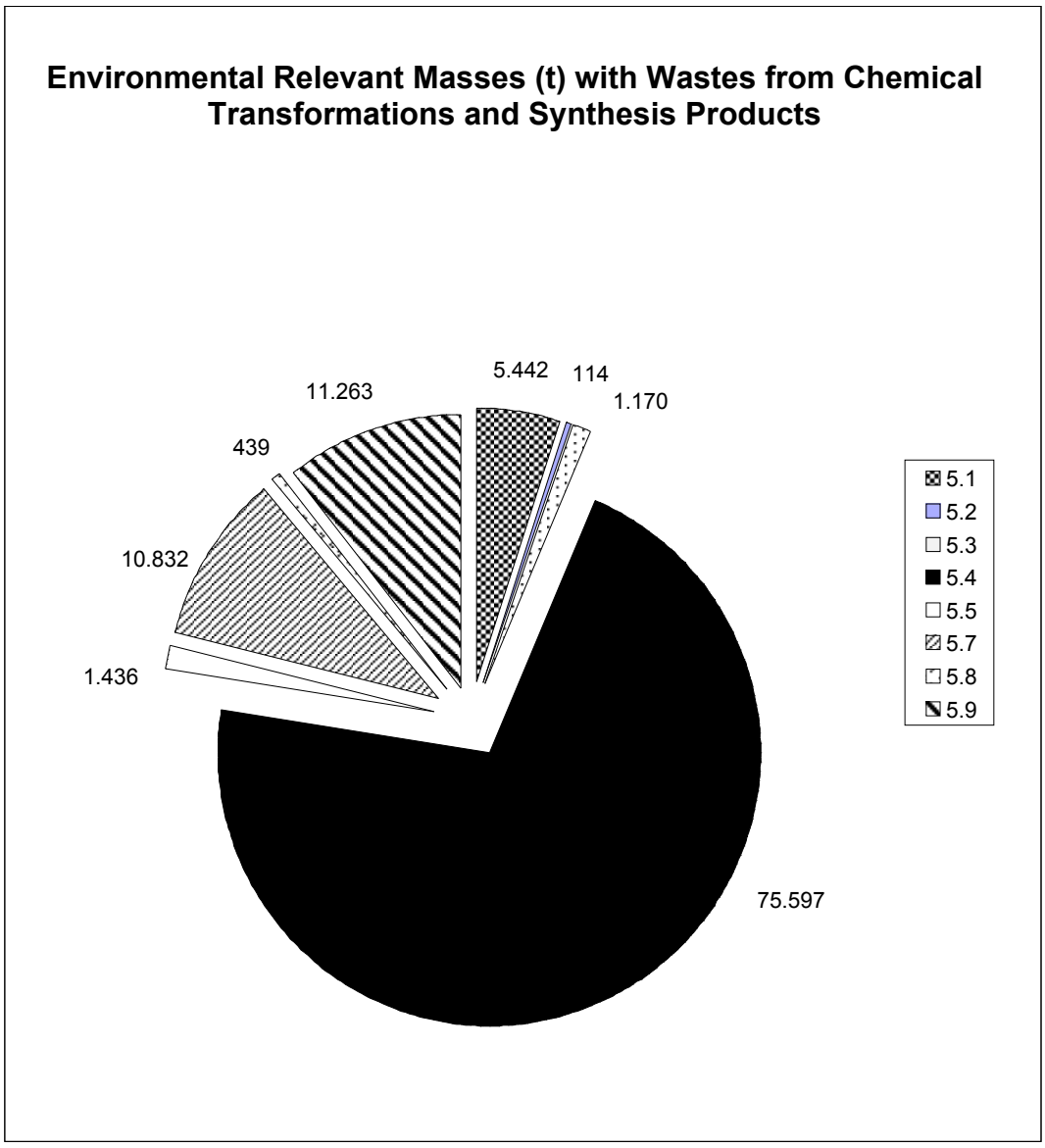

FIGURE 2. Estimated Environmental Relevant Masses in Tons (t) of Contaminated Site Materials from Wastes of Chemical Transformations and Synthesis Products (code No. 5) on SCSA of the WGT

The group of pollutants of 5.7 and 5.8 are dangerous materials for the drinking water supply of small importance. Relevantly are in particular the group 5.4 "petroleum products", further the group of 5.9 "other wastes of chemical production" as well as the group of 5.5 "organic solvents, paints, lacquers, adhesives, mastics, resins", in which for 148 SCSA is specified contamination with halogenated solvents. Despite the altogether very small estimated pollutant quantities of < 1% of the total loads, a high contamination potential for raw water is to be set for chlorinated hydrocarbons (CHC)[3]. This applies also to burials of all kinds, there here the

[3] The group of the halogenated solvents became - with appropriate specifications on the individual substances - in the WGT project reports only with 21 SCSA specified (1,2-dichlorobenzene - 7 ALVF, chlorobenzene - 1 SCSA, dichloromethane - 2

circumstances permitting possibly materials from special waste and munitions into the underground to be set free under the term "other wastes of chemical production".

Under the term "other wastes of chemical production" are combined, special chemicals and all military weapons. This concerns both explosives and chemical agents. Chemical agents come into question, however only in few exception cases as suspicious contaminants.

The very strong group 5.4 of the mineral oil hydrocarbons (MHC) covers quantitatively those dominating contaminated site materials, which causes substantial drinking water hygienic problems. To this belong the petroleum products diesels, gasoline, kerosene and other fuels, waste oils and PCB products as well as emulsions and mud from petroleum products.

In summary, following materials and group of materials can be determined as suspicious contaminants for drinking water relevant from military contaminated sites, due to the investigation of:

- fuels for tanks, commercial and passenger car,
- airport and missile propellants,
- hydraulics -, transmissions -, lubricating materials and antidegradants as well as waste oils of all kinds,
- chlorinated hydrocarbons e.g. trichloroethene and tetrachloromethane as solvents for tanks, engine and uniform laundry,
- weapon e.g. explosives such as 2,4,6-trinitrotoluole among other things,
- mineral acids as cleaner,
- lacquers and paints and solvents for lacquers and paints,
- glycol as anti-freeze,
- polycyclic aromatic hydrocarbons and dioxins from burn processes (also in the course of the evacuation of the properties)

A contamination potential by chemical warfare agents, that we found on armaments contaminated sites, could not be proved in the context of investigations on military sites.

2.2 ASSESSMENT

The specific difficulty in assessing the potential for chemical impairments to ground or row water from military sites is that used substances are often subject to secrecy, while their identification in a historical review of site-specific activities would greatly support situation assessment. Only if the substances to be expected are known, their hazard potential can be determined for a given site on the basis of substance-specific data. Investigations of the complex biophysical, chemical and biochemical transfer processes as well as of microbial metabolism of organics further supplement are the basis for a prognosis of the likely groundwater impacts in the recharge area, including contaminant fate, distribution, bioavailability, and degradation in the subsurface (Mulisch et al, 1996; Mulisch et al, 2000)

For the evaluation and classification of the hazard potential of military chemicals or compounds of contaminated sites we use the so-called substance-characteristic-system (SCS) as a modular constructed system for the complete assessment of environmental contaminants in drinking water in form of standardized coefficients (SC-values). On this basis, obtained chemical expositions and hazard potentials for humans and aquatic organisms can be recognized in time, quantified in soil and waters and repelled if necessary (Mulisch et al, 2003).

In the first precaution level of the risk assessment, the complex biophysical, chemical and biochemical transmission paths as well as the microbial metabolisms are systematised. It

SCSA, tetrachloroethene - 1 SCSA, tetrachloromethane - 2 SCSA, trichloroethene 8 ALVF). This, for the drinking water supply sometimes very problematic compounds, seems to be under represented in the WGT-project reports.

essentially covers the parameter SC_{BIO} for the biochemical degradation in the environment as well as parameters SC_{TOX} and SC_{AQU} for the harmfulness of the environmental contaminants in relation with the human organism and the aquatic environment. The mathematical operation of the individual SC-values results to the SC_{TOR} with the statement of the environmental toxicological relevance of the environmental contaminants. Supplementary substance specific mobility in the environment is measured as SC_{MOB} (see Table 2). In those cases, when SC-values

- predict a certain exposure and hazard potential or
- show an existing not early enough predicted exposure or hazard potential, that has to be repulsed

short to medium-term restoration decision are necessary (e.g. to the assurance of the hygienic harmlessness of drinking water for food purposes). The result of the first taking "precaution level" of the SCS-procedure must then, in the second "aftercare level" be supplemented through

- aqua toxicological substance assessments in form of aqua toxicological bearable maximum concentrations (BMC) or
- human toxicological substance assessments in form of health bearable guidance values for drinking water (GV).

TABLE 2. Representations of the Substance Characterisation Systems (SCS)

First Level: Substance Characterisation with SC-values		**Second Level: Hazard Characterisation**
Substance characteristics	Range of SC-values	Health guidance values for drinking water - GV $GV_{70,}$ $GV_{10,}$ $GV_{1,5,}$ GV_{SK} HSL
SC_{TOX}	1,0 - 4,0	
SC_{BIO}	1,0 - 2,0	
$SC_{TOX} + SC_{BIO} = SC_{TOR}$	2,0 - 6,0	
SC_{MOB}	1,0 - 4,0	
SC_{AQU}	1,0 - 2,0	Bearable Maximum Concentration in Waters (BMC)

Legend:
Substance Characteristics SC
TOX = Human Toxicity
TOR = Toxicological Relevance
ADS = Adsorptivity
BIO = Biochemical Degradation
SOL = Water Solubility
LOEC = Aqua Toxicological Threshold Values

GV = Hazard Characterisation over Health Risk Assessment
GV = Health Guidance Values
GV_{SE} = Guidance Values for Short Term Exposure
GV_{BI} = Guidance values for Babies and Infants for Short Term Exposure
HSL = Hygienic Sensory Limit
BMC = Bearable Maximum Concentration (Aqua Toxicity)

Formally the complete assessment of dangers from military areas and activities for drinking water respectively, is divided into an assessment complex with five parts of criteria, which cover the on side parameter on the basis of not sample criteria and local site investigation as well as the criteria of the substance characterization. "Characteristic numbers " necessary for the correct description of all results of the assessment criteria are measured on the basis defined work procedures and in the form of an evaluation raster by hazard levels (HL) for drinking water. From this, the necessary action need, can be derived through the safety precaution of the drinking water supply (see Table 3).

TABLE 3. Basis of the HL-Assessment Raster

Group	Statement/Consequence	Hazard Level
1	Statement: No hazard and no direct need for action regarding the drinking water supply Consequence: none	HL I - HL III
2	Statement: Potential or assume contamination of raw water in the catchments area of water supply plants Consequence: Immediate reconnaissance and investigation measures	HL IV
3	Statement: Missing data records; in individual cases contradictory statements in situation and investigation reports Consequence: Execution of appropriate searches	HL V
4	Statement: Proved hazard for the drinking water (acute exposition) and acute hazard suspicion through a high probability of expected contamination in the drinking water (latent exposition) respectively. Consequence: Direct need for action	HL VI

After the hazard statement, the clear health-referred exposure limits in form of measure values (short term health guidance values GV_{SE}) were designed in the context of human toxicological assessments as well as permissible bearable maximum concentrations (BMC) through aqua toxicological assessments and determined regarding the restoration needs.

The priority setting of a restoration needs is oriented thereby at the lowest of the both calculated values of aqua and human toxicity. If we have to take the human toxicological derived value for a substance, an additional calculation of the temporal priority setting of restoration measures is possible with the accumulation trend of this substance present in the human organism. This calculation of the temporal structuring of these measure values takes place in accordance with art. 9 of the European Union directive 98/83/EC.

3. Results

The international comparison shows strong differences between inventory, investigation, assessment and restoration of military suspicion contaminated site areas (SCSA) in environmental contaminations. A "phase wise" procedure is formalised in no other country except in Germany. The hazard based (retrospective) approach, identifies a toxic substance and introduces from a certain parameter value a corresponding measure, in order to eliminate the danger. In the frame of this work, additionally a prospective precaution assessment in the form of substance characteristics (SCS) is introduced and systematised.

The fact that an assessment result cannot obligatory certify the actual conditions is connected in particularly with the case of an uncertain or incomplete data situation. This case could be minimized with the fact that data gaps were also included into the assessment. But the individual substance assessments need a minimal inventory of data to be documented and it is necessary to take in consideration their quality and up-to-dateness. Eventual experimental data gaps are to be compensated over additional (facultative) statements and safety factors (SF), the results of the individual assessment and the complete statement must come very close to the actual condition. This methodology for the description and consideration of the data gaps into the assessment procedure is applicable in order to meet and to temporally clear insecurities during the assessment due to an inhomogeneous data situation until better data for the regulation are available.

The results of the accomplished investigations and assessments show, that from each third former WGT and/or part property respectively, there is a hazard potential for the drinking water supply (see HL IV to VI in Table 4). Immediate measures were introduced in 23 cases, in order to exclude a direct hazard for the human health. Over 80% of the examined former NVA-properties in Saxony were stated at the assessment, that a long-term effect of environmental contaminations cannot be expected to surrounding drinking water resources. On almost any fifth of these NVA-properties, suspicion contaminated site areas (SCSA) or still contaminated sites with water endangering toxic substances was determined, which represent a potential hazard of drinking water resources. Immediate measures could be introduced in 2 cases.

As a further conclusion it is recommended to include assessment criteria of the drinking water hygiene strengthened into the practical work of the inventory, assessment and restoration of military contaminated sites.

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