Helmut Klapper[a],
Walter Geller[a]

[a] UFZ Umweltforschungszentrum
Leipzig-Halle GmbH,
Sektion Gewässerforschung,
Brückstr. 3 a,
39114 Magdeburg,
Germany

Water Quality Management of Mining Lakes – a New Field of Applied Hydrobiology*

Underground and opencast mining generated many new lakes, some with dimensions comparable with natural glacier lakes. Research and water quality management on these lakes is multidisciplinary. A part of them is impaired by geogenic acidification with typical pH values between 2 and 3.5. Approaches are shown how to curb acidification during the mining process, the lake generation, and as a part of the water quality management by new ecotechnologies using alkalinity producing microbial processes. An interesting field is the extreme acidic environment and the adaptations of organisms and functioning of the biocenosis.

Review

Die Wassergütebewirtschaftung von Bergbauseen – ein neues Feld der angewandten Hydrobiologie

Unter- und Übertage-Bergbau haben zahlreiche neue Seen hervorgebracht. Die Dimensionen von einigen sind mit denen der natürlichen Glazialseen vergleichbar. Die Forschung an diesen Seen und die Wassergütebewirtschaftung sind multidisziplinär angelegt. Ein Teil der Seen ist durch geologische Versauerung mit typischen pH-Werten zwischen 2 und 3.5 beeinträchtigt. Es werden Wege gezeigt, wie die Versauerung durch Maßnahmen während des Abbaues, bei der See-Entstehung und als Teil der Wassergütebewirtschaftung mit Hilfe von mikrobiellen, Alkalinität produzierenden Prozessen in neuen Ökotechnologien verringert werden kann. Interessant ist das extrem saure Milieu als Lebensraum, die Anpassung der Organismen und das Funktionieren der Biozönosen.

Keywords: Geogenic Acidification, Acidic Environment, Multidisciplinary Research

Schlagwörter: Geogene Versauerung, Saures Milieu, Multidisziplinäre Forschung

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Correspondence: H. Klapper, E-mail: Klapper@gm.ufz.de

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1 Introduction: New landscapes, dominated by mining lakes

The majority of lakes in Germany are geologically young, originating from the glacier period. A lot of them, to be found on old maps, have disappeared by melioration, i.e. dewatering of wetlands and lake shores to gain arable land. Along natural rivers the halfmoon-lakes remind the historical courses, when rivers often changed their beds, especially after high floods. In our days in Europe nearly all rivers have a more or less constructed and fixed bed. The dynamics of river bed forming by meandering has disappeared, therefore no further old branches are generated.

Nevertheless more man-made lakes are born than natural ones are disappearing [1, 2]. Valleys are dammed as reservoirs, along some alluvial rivers the mining on sand and gravel produced large lakes. Quarries, out of operation, were flooded and some underground mines broke down, the hollow at the surface filling with water. The fastest increase in lakes is caused by closing most of the opencast browncoal mines in the eastern part of Germany. A hydrological problem now is how to satisfy the huge water demand for filling up the volume of $7.5 \cdot 10^9$ m^3 of the 160 emerging mining lakes and the deficit of the emptied groundwater layers of $13.5 \cdot 10^9$ m^3. Together the total demand is reported as $21 \cdot 10^9$ m^3 water [3]. In the brown-coal regions around Leipzig, Cologne and in the Lusatia region around Cottbus mining lakes will be the dominating landscape elements (see Fig. 1). Recultivated heaps will produce some relief energy, but first of all the many lakes will determine the beauty of the new forming postmining landscapes.

Whether people may live in this “new sea-land” and on what standard of living depends on the usability of the lakes. This is mainly a question of water quality. Also hydrobiologists are asked to gain the necessary knowledge for a target-oriented water quality management.

2 Mining technology and the later morphometry of the generated lakes

Old mines mostly are very small, compared with those of today. People found at first some pieces of lignite on or near the surface. In the “Muskauer Faltenbogen” ice pressure had caused the lignite seams to get in a vertical position and to reach the surface. 200 years ago land-owners began digging with spaden on that easy accessible material for heating and for burning brick or glass. More than 100 years old, the groundwater-filled lakes are acidic until now and nobody is able to spend the necessary money to improve actively the water quality. Water exchange is small. Wind protected in the forest, some of these lakes are stable stratified, i.e. meromictic [5] (see Fig. 2.1).

Until mid of the 20th century underground mining of browncoal was a widespread used technology. Now the mining pitwood is rotten and the underground vaults are broken down. On the surface above that mines shallow lakes are emerging. Because the fertile topsoil at the bottom of the new lakes, they are eutrophic from the very beginning (see Fig. 2.2).

All characteristics of high-mountainous oligotrophic lakes may be found in closed quarries. Stone braking often creates voids with vertical walls, so that the following lake will be nearly without a littoral zone. The thermal stratification in such a windprotected quarry-lake may be very stable, the detention time may be high (see Fig. 2.3).

Modern mines operate opencast and often with huge conveyor belt bridges. Their bucket wheel excavators are cutting the overburden layers above the coal and dumping it in the empty part of the mine. The coming mining lake corresponds to the mass deficit from the lignite, mined by other excavators and transported out of the mining hole. The opencast process heavily disturbs the hydrologic regime from the first preparation. The whole mining area has to be dewatered below the coal to be mined. The ratio of withdrawn water to extracted lignite may be from 100 % to more than 1000 %. Along with dewatering, the sulfur-containing minerals pyrite and marcasite come into contact with oxygen-containing air instead of oxygen-poor groundwater. This may lead to geogenical acidification and to many consequences on the ecosystems and the usability of the mining lake. The size of some of the youngest lakes to be flooded is huge. Some of them are bigger than the biggest reservoir in Germany, the Bleiloch Reservoir on the upper Saale, containing $200 \cdot 10^6$ m^3 (see Fig. 3).

3 Water quality management as an interdisciplinary task

A planful water management along with the mining process may be successful, when the diverse scientific disciplines cooperate well, to solve the complex problems. The share of the different disciplines involved are outlined only with keywords (see Table 1).

The many disciplines, taking part in the process of water management are a consequence of the general diversification of all sciences. Therefore, to facilitate the interdisciplinary understanding and networking, members have to be ready to learn at least some of the special terminology of the different disciplines, thereby obtaining a common understandable language within the working group. The object “water quality management” needs this type of scientist, being able to correspond with the other partners in the team.

Managing the water budget during the mining process for a long time was done mainly by geoscientists, miners, and

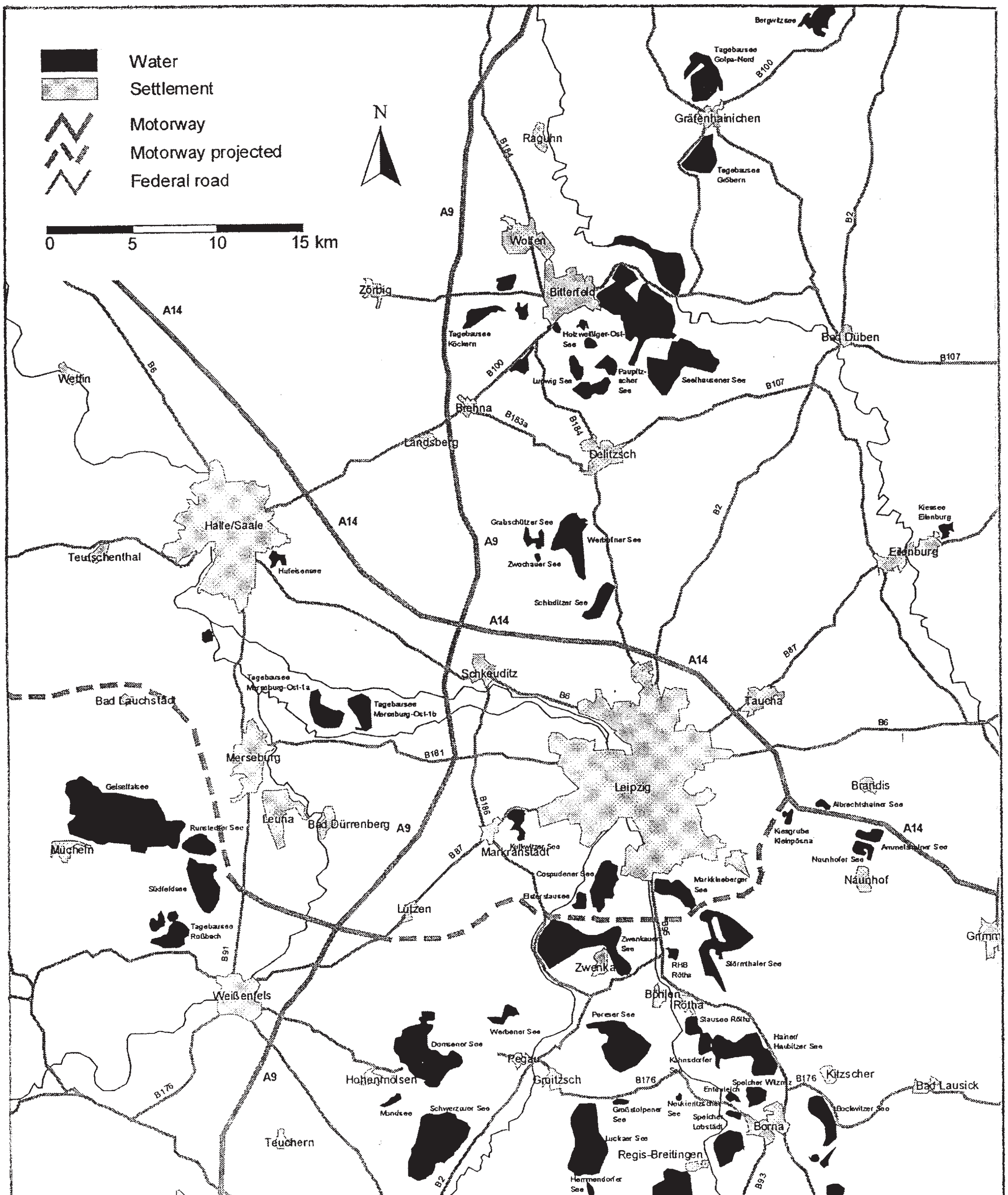

Fig. 1: The future lake district in the central German coalfield (after LMBV, from [4]).
Der künftige Seenbezirk im Mitteldeutschen Braunkohlenrevier (nach LMBV, aus [4]).

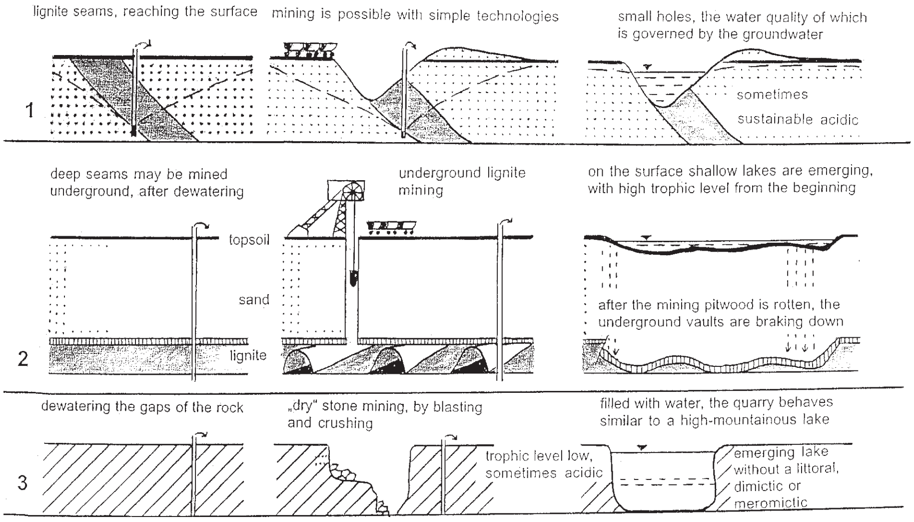

Fig. 2: Historical mining and the emerging mining lakes.

Historischer Bergbau und daraus hervorgegangene Seen.

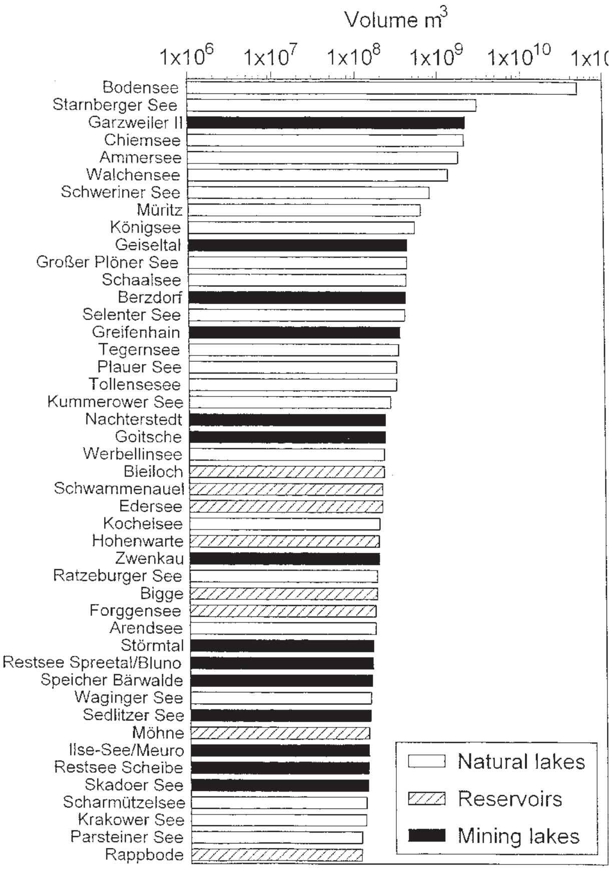

Fig. 3: Overview of the 45 largest lakes in Germany, including the coming mining lakes, arranged after their volumes (from [6]).

Übersicht über die 45 größten Seen in Deutschland einschließlich der künftigen Bergbauseen, geordnet nach ihrem Volumen (aus [6]).

hydrologists. The qualitative, esp. ecological, role of the mining was considered later. Meanwhile limnological expertises and prognoses are important items on the way to a functioning lake landscape and lake utilization. Many decisions of the recultivation plan and of its technical realization are based on the results of limnological investigations and recommendations of (micro)biologists, hydrochemists, and hydrophysisists.

As a last step of taking possession of the new man-made lakes the water quality has to be improved with help of ecotechnologies to meet the qualitative demand of diverse users, where ever necessary.

The user relations management is mainly organized by the staff of the Environment Protection Agencies, to day in Europe on the basis of the water framework directive from December 2000. The expression "management" implicites the possibility of taking active influence on water quality. Management means controlling by doing something, to make the ressource water more available and better usable for human and human society. At the same time the water bodies in the whole are habitats for plants, animals, and microorganisms. Therefore not only the criteria of usability of the water are of interest but also additional criteria of a management of the water body have to include the field of ecology, for example: biological balance and stability, self-purification, oxygen supply, sustainability, and, in the case of acidic mining lakes, the buffer capacity and the ability of neutralisation by microbial processes.

To gain safe fundaments for decision-support systems, the management should be as much as possible holistic and interdisciplinary. Related to the object "water" the holistic approach includes all parts of the water budget: running and stagnant waters, surface and groundwaters. The different

Table 1: Water quality management of mining lakes – an interdisciplinary task.

Wassergütebewirtschaftung von Bergbauseen – eine interdisziplinäre Aufgabe.

A) Water budget

Geology: Mining materials, mining depth, geochemical background of groundwaters and mining lakes (salinity, hardness, acidity, geogenic loadings...)

Geohydrology/Water engineering: Dewatering before mining, restoration of the water budget after mining, modelling of the groundwater regime ...

Mining/Mining engineering: Lake forming by mining: Volume, depth, area, shore slope, sliding danger, resp. safety...

Hydrology: Origin of the filling water, water table, exchange with the groundwater, detention time, water budget with precipitation, infiltration, storage, evaporation and runoff

B) Ecosystem functioning

Hydrobiology/Limnology/Microbiology: Life conditions, evolution of new ecosystems, prognoses/modelling, problems with acidity: photosynthesis without HCO_3^-, growth limiting factors P, N, C, light..., shortened food chains without fishes, snails etc.

Hydrochemistry/Limnochemistry: Adaptation of water analyses to different matrices: low pH, high concentration of iron, other heavy metals and sulfate...

Hydrophysics/Limnophysics: Temperature and density regime, stratification and mixing, throughflow pattern, internal waves ...

C) User relations - Management

Ecotechnology: Developement and application of technologies to control acidity, eutrophication, contamination...

Ichthyology: Fishery and acidic waters, fishbreeding

Sanitary engineering: Bathing and acidity, drinking water supply, sewage treatment

Sociology: Planning and managing water utilizations: fishery, recreation, water supply, nature protection, reservoirs for runoff control; validation of the man-made water resources, consequences on the labour market ...

Policy: International cooperation in research and development, border-crossing problems with water amount and quality, pollution conflicts with political importance, financial questions...

waters are interrelated among one another and interconnected with the terrestrial landscape and also with the atmosphere. All together are subject to climatic development, e.g. the global warming and its impacts.

Table 2: Mining lakes and utilizations: problems of applied hydrobiology.

Bergbauseen und ihre Nutzungen: Probleme der angewandten Hydrobiologie.

Utilization/activity	**Hydrobiological problems/ solutions**
commercial **Fishery** sportsfishery	acidity tolerance, pH-correction to > 5, stabilization of pH by carbon from net containers (?), fish ponds for sealing acidic heaps; eutrophication by vendace (?)
Recreation: bathing, diving, surfing, canoeing, water-travelling	correction to standard-pH > 6 or balneological utilization of the acidic waters? corrosion of metallic boats and equipment
Drinking water	replacement of the long-distance water supply? problems with high concentrations of Fe, Mn and SO_4^{2-}. Insufficient developed biofilm as a microbial barrier for slow-sand (bank-) filtration
Water storage (storage of high flood) (addition to low-water)	water table variations, littoral without reed belt and biological protection; very high elution rate of aciditiy from the repeatedly aerated geological surrounding; prognoses necessary for the acidity discharge, for storage and water quality
Deposals	filling the hollow space with inert material (tailings, ashes, rubbish), ecotoxicological risk evaluation of pollutants, assessment of subhydric depositions
Nature protection	non-using of the raw heaps increases the acidity export into nearby situated lakes, resulting in species-rich land fauna and flora beneath species-poor sulfur-acidic lakes
Monitoring and research	(research-) monitoring network, investigation, risk assessment, classification, modelling, expertises
Technology and development	strategies and technologies to control acidity, salinization, eutrophication, loading with microbes and chemical pollutants, management

A lot of neighbouring fields for investigation and research are in touch and with complex interdisciplinary methodology a successful management may be realized with benefit also for the life conditions in the mining lakes. The responsibility is shifting from geosciences during the planning and performing of the mining, to water-related sciences during preparation and flooding of the lakes and to social sciences while preparing a sustainable utilization of the lakes in the postmining landscape [4, 7].

In connection with the utilizations of the mining lakes by the diverse social users as well as for nature protection and for development of suitable ecotechnologies a lot of problems in the field of applied hydrobiology are waiting for their solution (see Table 2).

Hydrochemists have to adapt water analyses to the acidic and iron-containing solutions. Hydrophysisists are engaged with the forces of throughflow, stratification and mixing as parameters in the matter budget of the lakes. Hydrologists are looking for the water balance in the lake landscape.

One decision in the field of healthcare has to be settled as soon as possible, wether the acidic waters may be used for bathing, possibly with balneological or medical effect. In case, when some of the objects would be accepted by the society also under acidic conditions, neutralizing costs may be saved.

4 Man-made lakes and their successions compared with natural water bodies

In the last stages of the active mining, many deciding steps are taken to prepare the future lake for the coming use by the public. What shape the lake basin will have, what maximum and mean depth, in what relative position to the natural groundwater flow-direction the mining process has finished etc.

Greatest danger during the filling process stems from the overburden heaps, where they are forming the shore of the mining lake. Because of the relatively loose layering of the excavated overburden materials big sand slidings with sometimes millions of cubicmetres sand have happened and men lost their lifes in several sliding accidents.

Mining enterprises spent much money to obtain shallow banks with slopes from 1 : 10 until 1 : 20 inclination, being also suitable for bathing. Nevertheless by the laws of nature wind and waves and the erosive power of water in motion transform the shore slopes analoguous like in natural lakes. The uppermost part of the prepared bank is eroded by the waves. The lake grows in the first years of existence in its area. After some decades, also the mining lake has the profile as it is known from natural lakes in the loose-rock region. On the land side it begins with a steep cliff, followed by a flat shorebank that may be used for bathing purposes and the so called heap, built from eroded shore material. In the deepest part of the former opencast mine the lake bottom is covered at first by flocculated iron hydroxide, later by sedimented algae. The deepest parts are covered first, so by the "funnel-effect", the bottom finally is smooth and even (see Fig. 4).

The successions, we can observe at the glacier lakes with help of paleolimnological investigation methods along with the ageing, in principle are to be seen also on the mining lakes. Because of the higher nutrient supply today, the same processes are running much faster. What has happened during the 10 000 years after the glacier may be observed during some years or some decades. Sediment cores may answer, whether the pH has changed in the past and what organisms were able to settle in the extreme environment during the first years of existence of the mining lake [9].

A typical case study stems from lake Barleber See near Magdeburg, Germany. During wet excavation the fine silty particles of the sand and gravel are washed out. The water is turbid and algae growth is limited by the environmental factor light. Biological productivity is low also because of phosphorus-binding behaviour of the silt. After the finish of gravel excavation the inorganic particles settle on the bottom, the water becomes extremely clear. Macrophytes, gaining the nutrients from the ground are growing and are spread over the whole lake area and to the greatest depth of 11 m. The character of a macrophyte-dominated clearwater-lake prevailed round about 30 years. Degrading plant material consumed the oxygen in the depth and along with the switch to anoxic conditions a redissolution of phosphorus in concentrations of milligrammes per litre in the sediment-near water layers appeared. All macrophytes on the bottom died and from this time lake Barleber See was dominated by the phytoplankton. On the dark bottom with black sediments no macrophytes could grow. The now eutrophic lake with its expensive facilities for recreational activities was especially impaired by a mass development of bluegreen algae during the warmest season (see Fig. 5).

In 1986, the lake was restored by spreading of 470 tons of phosphorus-binding aluminium, i.e. aluminium sulfate as liquid solution on the 1 km^2 surface of lake. Since 1987, the year after phosphorus-flocculation, waterblooms of bluegreens have disappeared and macrophyte standings on the lake bottom have established again. By a longterm monitoring this impressious result is documented and shows that the 30 years "younger" lake has until today enough phosphorus-binding capacity to resist new eutrophication. Because the P-binding flocculant Al^{3+} is redox-independent also under anaerobic conditions, the phosphorus redissolution till today is really negligible [11, 12]. The high stability of the very acidic

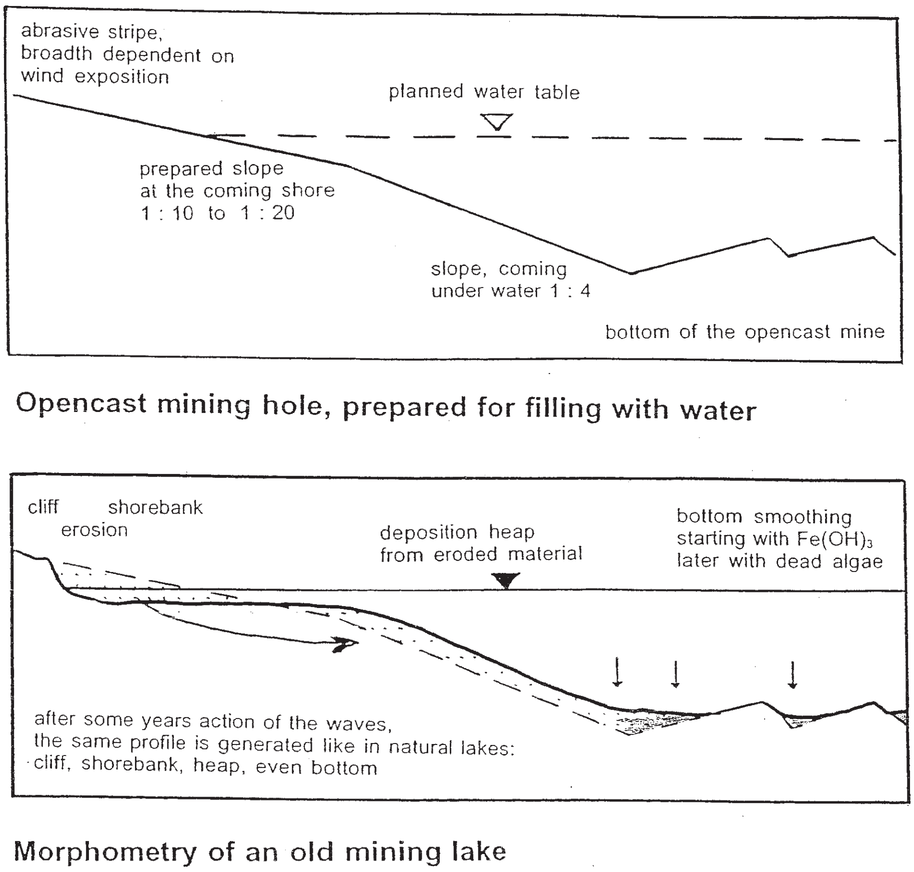

Fig. 4: Shore configuration of a mining hole, ready for filling with water (above) and some decades later, being overformed by natural forces (bottom) [8].

Ufergestaltung eines Bergbaurestloches, das zur Flutung präpariert wurde (oben) und einige Jahrzehnte später, nachdem das Ufer durch die Naturkräfte überformt wurde (unten) [8].

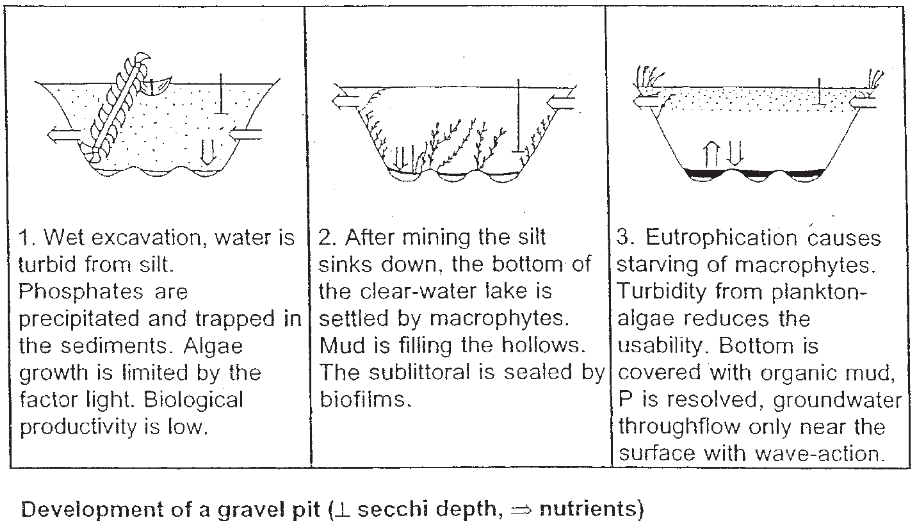

Fig. 5: Typical succession stages of a wet-excavated gravel pit [10].

Typische Sukzessionsstadien eines nassgebaggerten Kiessees [10].

old mining lakes (see Paragraph 2) was at first caused by a very small exchange of groundwater and by the restricted topography in the forest. Lake Barleber See on the other hand is intensively used for recreation and is wind exposed. A quality change was achieved by active control with help of a phosphate flocculation.

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5 The extremely acidic lakes – a challenge in water management

5.1 The geogenic acidification

Pyrite and marcasite, both ferrous disulfide, are immanent ingredients of lignite and of overburden layers. Before mining the groundwaters had been anoxic. FeS_2 is stable, the groundwater in the undisturbed ground is neutral. The mining process starts with dewatering. FeS_2 comes into contact with the air and thereby with oxygen. The first products are sulfuric acid and Fe^{2+}, the pH drops to about 5...6. Where this water from the heaps is filling the mining void, the Fe^{2+} hydrolyses to Fe^{3+}-hydroxide and the pH is dropping to 2...3.5. The most acidic waters are found in the mining lake. The water is iron-buffered, rich in sulfate and calcium, i.e. the waters are extremely hard by gypsum. Acid-soluble heavy metals are present in relatively high concentrations, especially the iron, stemming from pyrite (see Fig. 6). In Figure 6 the processes of acidification are demonstrated with an example of a groundwater-filled mining lake. In part 3 of this figure those processes are outlined, turning the acidification with help of biological mechanisms in the direction of neutralization [13, 14].

5.2 The acidic environment and ecological consequences

From the available literature on acid rain and its impact on waters, it seems that hardly any life can be expected at a pH less than 4 [15]. Nevertheless, such an extremely acidic habitat has been shown to be colonized by tolerant ubiquists, some of them in great abundance because of the lack of competition [16]. Compared with natural lakes, acidic mining lakes generally have a low primary productivity. Bicarbonate is not available, therefore algal groups of the *Scenedesmus* photosynthetic type are absent. The first phytoplankton to appear are from the same groups to be found in bog waters: chloromonads, cryptomonads, dinoflagellates etc. Pioneer genera are *Chlamydomonas* and *Ochromonas*, being able to live also heterotrophic or mixotrophic [17, 18].

Important processes occur at the level of the pico- and bacterioplankton. Also the seepage waters from overburden heaps with a pH < 2 are not really abiotic. At least bacteria occur in these waters. The pyrite oxidation itself is described as a chemo-autotrophic microbiological process catalyzed by some species of *Thiobacillus.* A chemical oxidation takes place too, but much more slowly compared with the microbiological process [19, 20].

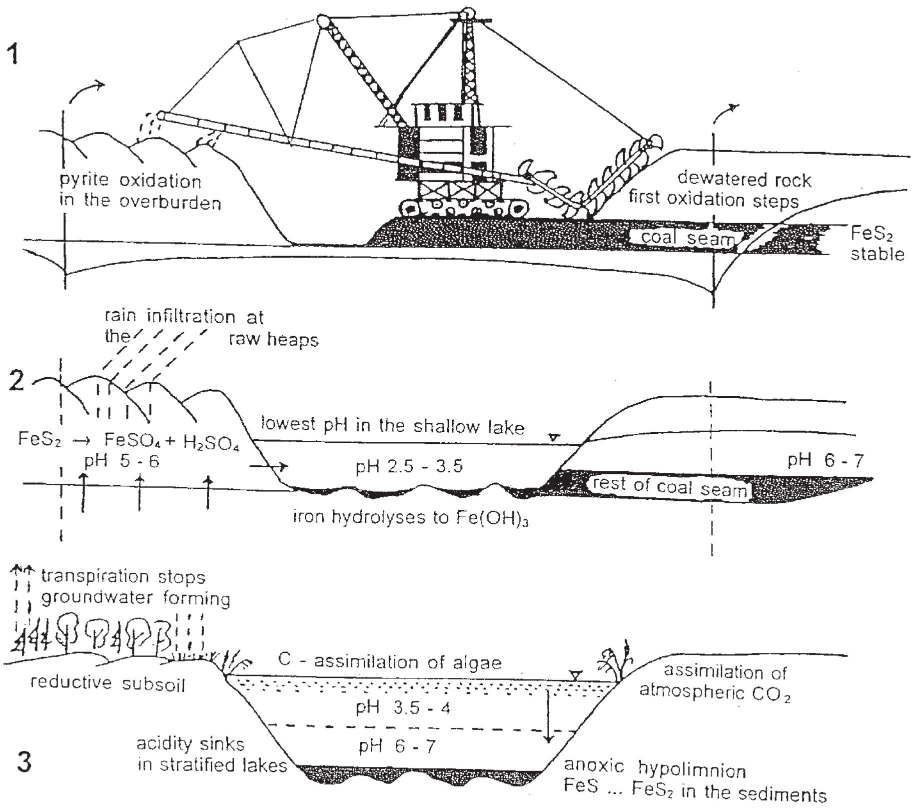

Fig. 6: Opencast mining on pyrite containing lignite. Reasons for acidification (middle) and for neutralization (bottom) [13].

Übertageabbau von pyrithaltiger Braunkohle. Ursachen für die Versauerung (Mitte) und für die Neutralisierung (unten) [13].

Soon after the hydrological regime has stabilized, the typical pioneer plant *Juncus bulbosus* occurs, followed by *Potamogeton natans, Utricularia minor, Sphagnum cuspidatum, S. obesum, S. inundatum* and the fern *Pilulifera globulifera.* The full species diversity is reached with circumneutral conditions. The reed belt developes relatively independent of the mining lake but in relation to the shore stability [21–23].

Of the animals, those groups cannot exist in an acidic environment, which need calcium carbonate for their skeletons or shells, such as fish, amphibians, snails, mussels, and higher crustaceans [24].

Zooplankton starts with some species of rotifers, ciliates inclusive suctoria and with pH > 3 the first specimens of *Chydorus* and *Cyclops*. From the rotifers of the acidic lakes often are mentioned *Brachyonus urceolaris, Cephalodella hoodii, C. gibba* and *Elosa woralii* [25, 26]. REM-records reveal that *Brachyonus sericus* has a different surface structure and a higher tolerance against low pH than *B. urceolaris.* So it is obviously an own species, as in the first description by Rousselet (1907) recommended and not a phenotype of *B. urceolaris* [26].

Very short nutrient chains are typical in acidic environments. In the groundwater-fed mining hole Niemegk (part of the opencast mine Goitsche near Bitterfeld, Germany), the plankton consisted besides bacteria and some pigmented flagellates *(Chlamydomonas, Ochromonas)* of Ciliates (with *Oxitricha* and *Vorticella* dominating) and a population of the heliozoa *Actinophrys* sol as a top-predator [27].

Daphnia needs neutral conditions and cannot be found in acid lakes. The bottom is inhabited by chironomids serving as the food basis for abundant corixids. These occupy also the free water, because they are already the top predators, where fishes are absent [28, 29]. So, with shortened food chains and with simple relations between the different parts of the ecosystem the extreme habitats may be used for ecological basic research.

5.3 Ecotechnologies to control the acidity

The bigger mining lakes should be usable for fishery and recreation and thus in the case of acid lakes neutralization is necessary. The liming of acidic lakes has been successful in some thousands of Scandinavian and American rain-acidified softwater lakes. In the case of the far more acidic, iron-buffered hardwater mining lakes the chemical demand would be at least tenfold higher so that liming is excluded by economical reasons.

Many activities **in the drainage basin** are suitable to minimize the acidity input into the lakes. Recultivation with forests curbs the groundwater forming and with this the vehicle of acidity generation and acidity transport.

High level of fertilization and organic supply of the recultivated heaps changes the conditions in the underground towards pyrite forming or acidity binding. Also the establishment of wetlands or fishponds filled in from running waters may

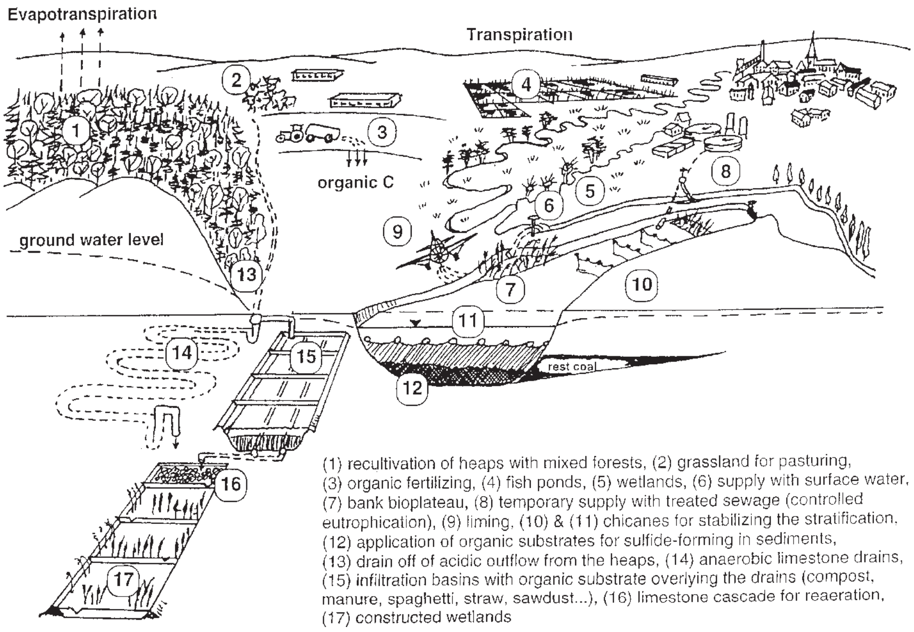

Fig. 7: Measures in the drainage basin, in mining lakes and outflows to curb the acidification [13].

Maßnahmen im Einzugsgebiet sowie in den Bergbaurestseen und deren Abflüssen zur Minderung der Versauerung [13].

hinder the further pyrite oxidation in the underground below (see Fig. 7).

In the lake the target-metabolism to bind acidity and to deliver alkalinity is the microbial sulfate reduction. All what is known about eutrophication and measures against it has to be reconsidered in order to understand and to solve acidification problems. Sulfate reduction needs an anaerobic environment. In the nature this occurs in the deep water of stratified lakes, in organic sediments, in the rotting plant material on the bottom of reed standings, or in the layers of leafs which had fallen into the water. Degradable carbon may have been introduced together with the filling water, or added exclusively for degradation and oxygen consumption, or might have been produced autochthonously with or without a stimulating nutrient addition to the water body.

A fast neutralization has been achieved in Great Britain with addition of a solution of phosphorus fertilizer into a softwater acidic mountainous lake. 5.9 m^3 of the phosphorus solution had the same neutralizing effect as 34 t $CaCO_3$ [31, 32]. Also to restore the nutrient nets in lakes, impaired by acid rain and neutralized with lime a moderate fertilization may be useful [33].

The stratification should be stable in order to keep away the oxygen at least some month each year from the hypolimnion or, in the case of meromictic lakes, from the monimolimnion. Floating barriers against wind and wave action may be installed, to avoid too early full circulation. Experiments within running research projects include pilot scale approaches with addition of straw together with carbonation lime from sugar factories [34], with potatoe peelings and with nutrients for stimulation of the autochtonous algae production [35, 36]. The reaction of the whole ecosystem is investigated and the data gained are generalized by ecosystem modelling. Some research centres and universities are in cooperation to answer the scientific questions in order to prepare the prerequisites for applied ecotechnologies.

Some **ex-situ technologies** for neutralization of lake outlets or mine outlets (Acid Mine Drainage, AMD) are included in Figure 7 (see Fig. 7). Alkalinity production or acidity binding is best accomplished in fully or partly anaerobic systems, while the precipitation of unwanted heavy metals is best achieved in aerobic macrophyte systems after the pH has risen to neutrality. Many proposals comprise combinations of anaerobic with aerobic steps, sometimes with limestone as an inherent constituent of the various stages of mainly biologically functioning ecotechnologies. For example, anoxic limestone drains (ALD) are widely used in the U.S. to satisfy the alkalinity requirement of acidic and metal-containing effluents. Anoxic operation is necessary to avoid clogging by the precipitation of metal hydroxides [37]. As the last step constructed wetlands and oxidation ponds serve the aerobic polishing of anaerobic neutralized waters [38]. Some drained infiltration ponds are constructed with a ground layer of limestone, covered with an organic mushroom compost. The water that has passed the "successive alkalinity-producing systems" (SAPS) is anoxic, but neutral [39, 40].

Summarizing the acidification problems it appears that the abatement of acidification includes measures to combat pyrite oxidation, steps to decrease groundwater and acidity transport, as well as in-situ and ex-situ neutralization technologies. Large mining voids primarily should be flooded with surface water containing bicarbonate. A temporarily higher trophic level has to be tolerated as an ephemeric state and may be tolerated because of the many natural processes of self-purification and phosphorus elimination by iron precipitation in the first stages of new mining lakes.

The most promising alternative for chemical neutralization is the encouragement of microbial processes of anaerobic binding of the acidity by desulfurization. Aerobic treatment with macrophyte systems, such as in artificially constructed wetlands, is suitable for polishing the water by flocculation of the heavy metals contained as hydroxides.

6 Conclusions

Along with mining activities and the many generated new water bodies, applied and basic hydrobiology is confronted to many new questions to be answered. On the level of the time, the water management has to be performed multidisciplinary to find holistic solutions. A special challenge are the sulfur acidic lakes with pH values of about 2...3.5, the water being iron buffered and with high concentrations of metals.

An urgent need exists in the research of microbial metabolisms producing alkalinity, i.e. the way back from acidification to neutralization. The prognosis and modelling to determine the acidity potential of the heaps and of the geological ground of the coming lakes are tasks for the near future.

With the knowledge of the processes of biological neutralization the adequate ecotechnologies are to be developed to stimulate the wanted metabolisms by technical measures and to create better usability of the lakes in question.

Evidently water quality management and lake usability touches social and political questions, too. Solutions are of interest international for all countries, mining on sulfidic ores and on ressources with sulfides in the overburden. The wanted holistic approach is a challenge today and in the near future. It needs researchers, being open to all disciplines involved and ready for a broad and fruitful cooperation.

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