UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF INTERNATIONAL AFFAIRS
AND
REGION III
MID-ATLANTIC STATES

REPORT ON

RECLAMATION OF TOXIC SPOIL STACK FOR VARIOUS SELECTED SOIL CONDITIONS WITH THE TUROW LIGNITE MINE AS AN EXAMPLE

BY

CENTRAL RESEARCH AND DESIGN INSTITUTE
FOR OPENCAST MINING
"POLTEGOR" – WROCLAW, POLAND

JANUARY 1976

SCIENTIFIC ACTIVITIES OVERSEAS

(Special Foreign Currency Program)

Scientific Activities Overseas, Developed and implemented under the Special Foreign Currency Program, are funded from excess foreign currencies accruing to the United States under various U. S. programs. All of the overseas activities are designed to assist in the implementation of the broad spectrum of EPA programs and to relate to the world-wide concern for environmental problems. These problems are not limited by national boundaries, nor is their impact altered by ideological and regional differences. The results of overseas activities contribute directly to the fund of environmental knowledge of the U. S., of the host countries and of the world community. Scientific activities carried out under the Program therefore offer unique opportunities for cooperation between the U. S. and the excess foreign currency countries. Further,the Program anables EPA to develop productive relationships between U. S. environmental scientist and their counterparts abroad, merging scientific capabilities and resources of various nations in concerted efforts toward U. S. objectives as well as their own.

Scientific Activities Overseas not only supplement and complement the domestic mission of EPA, but also serve to carry out the mandate of Section 102(2(E) of the National Environmental Policy Act to „recognize the world-wide and long-range character of environmental problems, and where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment".

This study utilizing the Turów open pit lignite mine has been funded from Public Law 480. Excess foreign currency money is available to the United States in local currency in a number of countries, including Poland, as a result of a trade for U. S. commodities. Poland has been known for its extensive mining interests, environmental concern, and its trained and experienced engineers and scientists in this important energy area.

This report has been reviewed by the Environmental Protection Agency and has been approved for publication. Approval does not signify that the contents necessarily reflect the views of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

DATE: JUNE 30, 1976

REPORT ON

RECLAMATION OF TOXIC SPOIL STACKS FOR VARIOUS SELECTED SOIL CONDITIONS WITH THE TURÓW LIGNITE MINE AS AN EXAMPLE

BY

KAZIMIERZ BAUMAN, PRINCIPAL INVESTIGATOR
POLTEGOR

PROJECT NO. 02-532-11

PROJECT OFFICERS:

EDGAR PASH (Formerly with EPA, now with Department of Interior)

AND

SCOTT MCPHILLIAMY, EPA, REGION III

Prepared for

Office of International Affairs
U.S. Environmental Protection Agency
Washington, D.C. 20460

C O N T E N T S

DATE: JUNE 30, 1976

REPORT ON

RECLAMATION OF TOXIC SPOIL STACKS FOR VARIOUS SELECTED SOIL CONDITIONS WITH THE TURÓW LIGNITE MINE AS AN EXAMPLE

BY

KAZIMIERZ BAUMAN, PRINCIPAL INVESTIGATOR
POLTEGOR

PROJECT NO. 02-532-11

PROJECT OFFICERS:

EDGAR PASH (Formerly with EPA, now with Department of Interior)

AND

SCOTT MCPHILLIAMY, EPA, REGION III

Prepared for

Office of International Affairs
U.S. Environmental Protection Agency
Washington, D.C. 20460

C O N T E N T S

Page

1. LIST OF FIGURES

2. LIST OF TABLES

Page

Page

3. A C K N O W L E D G E M E N T S.

This final report has been prepared on the base of research project completed by the Central Research and Design Institute for Opencast Mining - the Poltegor in Wrocław, Poland.

In the project an assistance of surveillance stations of the Meteorological and Water Institute, of Health - Epidemiological Service, and first of all of the laboratories of the Mining Academy of Cracov has been used. The whole of project was directed and report prepared by Principal Investigator Mr. Kazimierz BAUMAN, M.Sc.

On the part of the U.S. Environmental Protection Agency, the project was supervised by the Project Officers: Mr. Edgar A. Pash, geologist, of the Office of Water Program Operations, Washington D.C. 20460, and Mr. Scott Mc Philiamy, from the EPA III Region, Wheeling. To both the Project Officers we extend our grateful thanks and acknowledgements for the assistance and advice rendered to us in the course of performed project. We appreciate also the helping us to get in touch with appropriate Institutions in the U.S.A. which in turn gave us the chance to get acquainted with the similar research in US and also to understand better the needs and requirements of the environmental protection and the reclamation in U.S.A. For the assistance in the organizational and in financial matters we gratefully acknowledge the good services of Mr. Thomas J. Lepine, the Chief of the Special Foreign Currency Program of EPA, the program that was providing the money for the project. We also extend our acknowledgements to the specialists from the United States Forest Service, the Virginia Polytechnical Institute, the Montana State University, Denver Research Institute, for the discussing of the project problems and for making us conversant with their research and also to the Peabody Coal Co., the Consolidation Coal Co., the Amax Coal Co., the Western Energy, Cemmerer Coal Co., the Pacific Power and Light Co., the Kennecot Copper Co., for familiarizing us with their effort regarding the reclamation of mined - out terrains.

4. S U M M A R Y.

The objective of the presented research work and of the prepared on it's basis report was the elaboration of reclamation technology for the toxic spoil stacks of the lignite surface mines. The main object of the carried out investigations were the problems of neutralization of soils with a toxicity induced in them by the presence and decomposition of sulphur compounds. The elementary sources of toxicity of the post - mining terrains of the lignite surface mines in Poland and U.S.A. are the ferric sulphides, the pyrites, the marcasites, pyrrhotites, hydrotroilites and some others.

These compounds on the spoil stacks are being transformed biologically and chemically into various combinations influencing directly or indirectly the development of the higher vegetation and the soil micro - flora. The character and composition of the toxic compounds depends on the concentration of the sulphides and also on the type of formations in which these sulphides are to be found, and also on the presence or absence of compounds of alkaline character. The presence of the sulphur compounds in the overburden in quantities inducing a strong acidification in soils is an unfavourable factor for the mining on the whole. For in such conditions takes place an increase of costs of exploitation, and the negative influence exerted onto the natural environment.

In extreme cases however, confirmed by the practice in the U.S.A. and in Poland, by a badly performed exploitation and reclamation operations there had been created post - mining terrains totally useless economically, and moreover constituting a threat to the neghbouring terrains, utilized by agriculture or forestry. With a good reconnaissance of overburden, carried out still before the mining operations commencement, taking into account in exploitation the needs of reclamation and of recultivation, through an adequately programmed management with overburden, and with rationally performed specilistic reclamation treatments, the troubles connected with the occurrence in overburden of the toxic formations can be diminished and often practically eliminated.

Taking into consideration the requirements of the mining industry, the attention was focussed mainly on the following issues:

- the elaboration of methodology for the formations' toxicity level determination,
- the elaboration of methods for the neutralization of toxic soils, on the spoil stacks in the adaptation to agricultural or forestral restoration,
- the elaboration of the neutralization technology for toxic soils, on steep slopes and the detailed rules for their biological cover inhibiting the erosion,
- the elaboration of a qualitative and quantitative composition of a vegetation initiating the soil reproducing processes, and actively contributing to the biological neutralization of toxic soils,
- the determination of appropriate agrotechnique for the reclamation operations,
- the elaboration of guide - lines for the management with overburden, having for its objective the liquidation or limitation of toxicity.

In assigning the scope of the research work, the respectively short period of time (3 years) in regard of biological research, was taken into account in the project realization. In order to mitigate this inconvencience it was decided to widen the experimental work to two objects - the external spoil stack of the "Turów" lignite surface mine, and the internal spoil stack of the "Przyjaźń Narodów" lignite surface mine. The experimental object "Turów" represented clayey and silty soils with the pH about 3,5, and the experimental object "Przyjaźń Narodów" provided sandy soils of pH about 2,7. On the "Turów" mine there was introduced grassy, papilionaceous, arborescent and shrub vegetation, and on the "Przyjaźń Narodów" mine was sown only grassy and papilionaceous vegetation.

The achieved results from the realized research indicate, that on heavy and acid soils, with a suitable selection of neutralizers and a pioneering vegetation and with a simultaneous mineral fertilization one can obtain a good production of grasses.

Determined in the course of studies was a number of qualitative and quantitative relationships, and the knowledge of these allowed to specify practical recommendations use ful for the staff conducting the mining and reclamation operations and as well as for supervision. The observation of these recommendations in the active mines will permit to carry the mining and reclamation operations in a more rational manner - and for planning it will permit to determine the most suitable spoils management and the resulting from it technologies of overburden removal, as well as the methods of spoil stacks shaping and reclamation. This should provide economic and social effects.

Moreover, the results of research work comprised in this report will allow to determine in more strict and useful manner for the further phase of research, which objective should be the precise specification and a widening of knowledge from this sphere.

The report was submitted in a fulfillment of the project, number 02-502-11 between the United States Environmental Protection Agency and the Central Research and Design Institute for Opencast Mining "Poltegor", Wrocław, Rosenbergów 25, Poland.

5. CONCLUSIONS.

1. Results acquired from investigations carried out on an external spoil stack of the "Turów" strip mine can be considered as representative for the mined out terrains with a toxicity with a toxicity caused in them by the presence of sulphur compounds in quantities inducing the pH reaction in KCL of 3,0 - 4,5 and, with average resources of nourishing compounds, the phosphorus excepting, with cohesive soils and a climatic zone of average annual temperature 7,4°C and average annual precipitation of long term 693 mm.

2. The results achieved from investigations executed out on the internal spoil stack of the strip mine "Przyjaźń Narodów" can be regarded as representative for the terrains worked out, with sulphurous toxicity developing an acid reaction of a pH in KCL being 2,8 to 3,2 and with sandy soils of a very low content of nourishing components and a climatic zone of average annual temperature 7,4°C and average long term annual precipitation of 629 mm.

3. Of the following tested neutralizers: agricultural quicklime, ground phosphate rock, ammonia water, on the test plots on "Turów", and magnesia lime, ground phosphate rock on the test plots on "Przyjaźń Narodów", the best effects were acquired with the application of a mixture of two neutralizers:

   In Turów - agricultural quicklime and ground phosphate rock
   In Przyjaźń Narodów - magnesia lime and ground phosphate rock.
   No encouraging results gave the application of ammonia water.

4. From the used various amounts of neutralizer doses the best effects gave the following applications:

   - in Turów - 5 t/ha of lime and 3 t/ha of ground phosphate rock
   - in Przyjaźń Narodów - 45 t/ha of magnesia lime and 5 t/ha of ground phosphate rock.

5. The investigations confirmed, that for sandy and strongly acidified soils the most advantageous introduction of neutralizers is in two layers. This probably comes from the fact of deeper penetration of plant roots in conditions of greater water deficiency so typical for permeable soils.

6. Tested on the slopes was the effectiveness of the performance of two neutralizers - agricultural lime in doses 5 t/ha and 10 t/ha, and ground phosphate rock in quantity of 3 t/ha. The neutralizers were introduced in a twofold manner - on the surface only, and on the surface and into the previously prepared pits. A comparatively short period of investigations (only two vegetation seasons of planted seedlings of trees and shrubs), did not allow yet to specify precisely the final conclusions regarding the effectiveness of applied neutralizers and methods of their application.

7. Carried out tests on mineral fertilization allow to state the following:

   - the best effects were achieved with the application of mineral fertilizers in few phases, i.e. in a starting phase and in the complementary fertilization outside the roots' phase,
   - for Turów a sufficing starting dose of fertilization was:
     N - 200 kg/ha in pure component
     P - 50 kg/ha in pure component
     K - 30 kg/ha in pure component
   - for Przyjaźń Narodów the investigations did not indicate what could be considered the optimal dose of fertilization,
   - the amount of fertilization outside the roots was determined on the basis of direct observations of plants,
   - for the betterment of chemical composition of plants necessary was employment of supplementary fertilization with magnesium and molybdenum fertilizers in amounts:
     P - 60 kg/ha in pure component, i.e. 300 kg/ha of treble superphosphate 46 %

Mg - 10 kg/ha in pure component, i.e. 101,5 kg/ha of magnesium sulphate

Mo - 0,20 kg/ha in pure component, i.e. 0,37 kg/ha of ammonium molybdate.

8. In conditions of clayey and silty soils of the Turów mine the most successful were: the Phleum pratense from grasses, and the Lupinus polyphyllus from papilionaceous plants, the latter developed well and the leading roots of particular specimens were reaching even 100 cm depth. A large amount of Rhizobium nodules on the roots of Lupinus proves its biological activity.

9. In case of toxic sandy soils of the Przyjaźń Narodów strip mine, deacidified with lime - magnesium or lime-magnesium phosphorous neutralizers, the must successful from among the Papilionaceae was the Lupinus polyphyllus, quite successful were the Lotus corniculatus and Trifolium reprens. Decidely unsuccessful was Melilotus albus. From amongst the introduced grasses during the first vegetation seasons the best were Agrostis alba, and Lolium multiflorum westerwoldicum. The observations of old fragments of the spoil stack, reclaimed before the year 1974 show that after a few years the Agrostis alba, Festuca rubra i Phleum pratense among the grasses began to dominate.

10. Amongst the introduced species of grasses, the Phleum pratense showed many positive characteristics. It probably is little sensitive to prolonging periods of dry weather, also indicates weak reaction to the soil medium acdification and to rapid reaction changes.

11. A quick stopping erosion on the slopes is possible with the employment of herbaceous vegetation. Considering in the above plants mixture the papilionaceous species too, promotes the development of soil reproducing processes and improves the growth conditions of introduced seedlings of trees and shrubs. Into the vegetation mixture accompanying the afforestations, in cases of conditions aproximated to the Turów mine, should be included:

Arrhenatherum elatius, Festuca rubra, and Phleum pratense only in small amount. From amongst the Papilionaceae the Melilotus albus should be eliminated.

12. In case of used for the neutralization the ground phosphate rock and the ammonia water, and not the agricultural quicklime, it is advisable to decrease the share of Papilionaceae in the mixture of plants, and especially of Trifolium repens and Lotus corniculatus.

13. The arborescent vegetation was growing on the slopes all too short, in order to be able to evaluate its successfulness precisely.

14. The costs of treatments itemized as particular investigated combinations for the economic comparison with their effectiveness are presented as follows:

Specification of costs of reclamation treatments on experimental plots of the lignite surface mine "Turów" (per unit of area according to prices in Poland).

No.	Specification of treatments	Costs indicator in thous - zł/ha
I.	Neutralization - Combination A - without neutralization (inspection plots) only cultivation treatments	1,2
II.	" " B - CaO in dose 5 t/ha, single layer	9,6
III.	" " C - CaO in dose 10 t/ha, two layers in this: - bottom layer (15 - 30 cm) - 5 t/ha, - top layer (0 - 15 cm) - 5 t/ha,	19,4
IV.	" " D - CaO in dose 5 t/ha and ground phosphate rock MF in dose 3 t/ha, in two layers, in this: - bottom layer - ground phosphate rock - top layer CaO	21,0
V.	" " E - ground phosphate rock MF in dose 3 t/ha in single layer	11,2
VI.	" " F - ground phosphate rock MF in dose 3 t/ha, and 25 % ammonia water in dose 5 m3/ha, in single layer	17,3
VII.	Fertilization - Combination X_0 - without fertilization (inspection plots) only cultivation treatments	1,1
VIII.	" " X_1 - NPK - where: N = 261,5 kg/ha in pure component, in form of urea and ammonium nitrate P = 32 kg/ha in pure component, in form of superphosphate K = 32 kg/ha in pure component, in form of potash salt	5,1
IX.	" " X_2 - N_2PK - where: N_2 = 488,5 kg/ha in pure component, in form of urea and ammonium nitrate P = 32 kg/ha in pure component, in form of superphosphate K = 32 kg/ha in pure component, in form of potash salt	6,8
X.	Introduction of vegetation on the top portion in a following composition and amounts: 1) Lupinus polyphyllus Ldl 25 kg/ha 2) Lotus corniculatus L. 8 kg/ha 3) Trifolium repens L. 3 kg/ha 4) Phleum pratense L. 3 kg/ha 5) Lolium perenne L. 3 kg/ha 6) Festuca rubra L. 3 kg/ha 45 kg/ha	36,4
XI.	Supplementary fertilization on micro-plots X_{11} - P_1Mg - where: P_1 = 60 kg/ha in pure component, in form of superphosphate	1,3
XII.	" " " " " X_{12} - P_1Mg - where: P_1 = 60 kg/ha in pure component, in form of superphosphate Mg = 10 kg/ha in pure component, in form of magnesium sulphate	9,9

No.	Specification of treatments	Costs indicator in thous - zł/ha
XIII.	Supplementary fertilization on micro-plots X_{13} - P_1MgMo - where P_1 = 60 kg/ha in pure component, in form of superphosphate Mg = 10 kg/ha in pure component, in form of magnesium sulphate Mo = 0,2 kg/ha in pure component, in form of ammonium molybdate	16,1
XIII/1	" " " " " X_{21} - P_1 - where P_1 = 60 kg/ha in pure component, in form of superphosphate	1,3
XIII/2	" " " " " X_{22} - P_1Mg - where P_1 = 60 kg/ha in pure component, in form of superphosphate Mg = 10 kg/ha in pure component, in form of magnesium sulphate	9,9
XIII/3	" " " " " X_{23} - P_1MgMo - where P_1 = 60 kg/ha in pure component, in form of superphosphate Mg = 10 kg/ha in pure component, in form of magnesium sulphate Mo = 0,2 kg/ha in pure component, in form of ammonium molybdate	16,1
XIV.	Cultivation treatments in the year 1974 - harrowing and twice done mowing of vegetation	2,6
XV.	" " " " " 1975 - " " once " " " "	1,8
XVI.	Neutralization of slopes - B combination - CaO in a 5 t/ha dose furnished outside roots	2,4
XVII.	" " " - C " - CaO in a 10 t/ha " " " "	3,4
XVIII.	" " " - D " - ground phosphate rock MF supplied in a 3 t/ha dose outside roots	4,0
XIX.	Slopes mineral fertilization uniform - NPK - where N = 139 kg/ha in pure component, in a form urea and ammonium saltpetre P = 32 kg/ha in pure component, in a form of superphosphate K = 47 kg/ha in pure component, in a form of potash salt	3,7
XX.	Introduction of grasses onto the slopes with a following composition and amounts: 1) Lupinus polyphyllus 30 kg/ha 2) Lotus corniculatus 10 kg/ha 3) Melilotus albus 5 kg/ha 4) Trifolium repens 3 kg/ha 5) Phleum pratense 4 kg/ha 6) Arrhenathesum elatius 4 kg/ha 7) Festuca rubra 4 kg/ha 60 kg/ha	44,0

No.	Specification of treatments	Costs indicator in thous - zł/ha
XXI	Afforestation of S–I Block with cuttings, as on table 9	80,9
XXII	" " S–II " " " " " " 9	85,4
XXIII	" " S–III " " " " " " 9	83,4

Specification of costs of reclamation treatments on experimental plots of the lignite surface mine "Przyjaźń Narodów" (per unit of area according to prices in Poland)

No.	Specification of treatments	Cost indicator in thous of T/ha
I.	Neutralization - Combination A - magnesia lime in dose 25 t/ha, in single layer	16,7
II.	Neutralization - Combination B - magnesia lime in dose 50 t/ha, in single layer	18,8
III.	Neutralization - Combination C - magnesia lime in dose 50 t/ha, in two layers - top layer (0-20 cm) - 40 t/ha - bottom layer (20-40 cm) - 10 t/ha	23,9
IV.	Neutralization - Combination D - magnesia lime in dose 45 t/ha and ground phosphate rock MF in dose 5 t/ha, in two layers: top layer (0-20 cm) - magnesia lime 40 t/ha bottom layer (20cm - 40 cm) - magnesia lime 5 t/ha and ground phosphate rock 5 t/ha	27,9
V.	Mineral fertilization in year 1974 - NPK - - where - N = 50 kg/ha in pure component in form of nitro-chalk P = 12 kg/ha in pure component in form of superphosphate K = 50 kg/ha in pure component in form of potash salt	2,1
VI.	Mineral fertilization in year 1975 - NPK - - where N = 75 kg/ha in pure component in form of nitrochalk P = 20 kg/ha in pure component in form of superphosphate K = 60 kg/ha in pure component in form of potash salt	3,8
VII.	Biological consolidation, combination M_1 - mixture no. 1 of papilionaceous plants with grasses: 1) Lupinus polyphyllus 30 kg/ha 2) Agrostis alba 8 kg/ha 3) Arrhenatherum elatius 6 kg/ha 4) Festuca pratensis 6 kg/ha 50 kg/ha	43,5
VIII.	Biological consolidation, combination M_2 - mixture no. 2 of papilionaceous plants with grasses: 1) Lotus corniculatus 20 kg/ha 2) Bromus inermis 8 kg/ha 3) Lolium multiflorum wester woldicum 6 kg/ha 4) Poa pratensis 6 kg/ha 40 kg/ha	3,6
IX.	Biological consolidation, combination M_3 - mixture no. 3 of papilionaceous plants with grasses: 1) Trifolium repens 10 kg/ha 2) Melilotus albus 5 kg/ha 3) Phleum pratense 8 kg/ha 4) Lolium multiflorum 6 kg/ha 5) Testuca rubra 6 kg/ha 35 kg/ha	2,6

6. RECOMMENDATIONS.

The Experiences obtained by the Openpit Mining in Poland and also in other countries indicate, that the most suitable effects from the reclamation and recultivation effort of the terrains transformed in the course of mining can be achieved only, when the problems of the said reclamation and recultivation are being considered with adequate accuracy at all stages of the minning activity - i.e. during the initial and detailed geological investigations, during the designing of a mine, its construction and during the whole period of mine life, and very often also after its ending.

The directions of the economic restoration of the mined out terrains (agricultural forest communal) and the methods and costs of the reclamation realization depend first of all on the kind of soils embodied in the subsurface zone of the transformed terrains.

An agricultural restoration can only then be considered, when the soils have at least average suitability for the reclamation, or in case of toxic soils, when their mineral material is valuable enough. In the remaining cases an appropriate line of restoration would be the forest line or the for communal use. Taking into account the above statements and the up-to-date practical experience concerning the particular elements of mining activity one can formulate the following general recommendations.

I. Geological and specialised investigation for the requirements of reclamation.

1. The investigations for the reclamation needs should begin already at the stage of geological prospection and should be conducted throughout the whole period of mining activity.

2. During the time of mining operations systematic laboratory and field tests of soils in the overburden and on the spoil stack should be performed with a frequency greater for the complicated geological structure but decreasing in due course with acquired experience.

3. In the examination of overburden a particular attention should be given to the separation of toxic from not toxic soils on the basis of properly elected set of analyses - for the Polish circumstances the tests of sulphur compounds contents (forming acids) and of the pH reaction belong to essential set of analyses.

4. The main lithological complexes in the overburden should be tested for the contents of micro - elements and for the radioactive substances.

5. For a fuller characteristic of soils both in the overburden and in the spoil stack, determinations of the chemical composition, of the carbonate content, of the plasticity index and of sorptive capacity should be performed.

6. The more accurate is the reconnaissance of the overburden soils, the smaller may be the qualitative and quantitative scope of the analyses of the spoil stack soils.

II. Mining operations.

1. The mining operations should be planned and conducted in such way, that the best soils of the overburden ought to be in-built into the subsurface zones of the terrains left after exploitation ended.

2. In the shallow openpit mines, with one seam ones, there on account of mostly occurring simple geological structures of overburden, small quantities of this overburden and also small displacement distances for ground masses from the working face to the site of stack - the method of covering the worked out terrains with top soil selectively removed from the working face foreground should be a rule.

3. In deep openpit mines characterized with a complicated geological structure of the overburden - the occurrence of several kinds of formations with very different physical - mechanical and chemical characteristics - one should employ a controlled management of overburden stacking.

4. When in the overburden of deep openpit mines a relatively small amount of toxic soils is occurring but degree of their deficiency for reclamation is considerable the overburden stripping transport and stacking, based on a controlled management with worst soils is recommended, (in order to limit their negative influence on the effects of reclamation and recultivation). In such cases is advisable to determine already at the stage of mine designing the most suitable methods:
   - placing in deeper layers of the spoil stack the worst soils and insulating against their influence with a thick layer of soils potentially productive,
   - adequate distribution of worst soils in the mass of soils potentialy productive.
5. When in the overburden of deep openpit mines exists a large quantity of bad soils from the point of view of reclamation needs the overburden stripping transport and stacking based on controlled management with best soils is recommended. This model is typical for agricultural direction of restoration, as the basic assumption for this model should be the acquisition - on the mined out terrains - of soils with a high production capability.
6. The uncontrolled overburden stripping transport and stacking, ought to be employed only then, when the method of the overburden removal and its stacking had no bearing on the direction of recultivation. This model is typical for the silvicultural direction of restoration.

III. Shaping of spoil stacks.

1. The shaping should be effected in such a way as to preserve the possibility of consecutive execution of reclamation and recultivation.
2. The formation of spoil stacks highly elevated or depressed in relation to the natural terrains surface should be avoided.

3. In shaping of single slopes and of systems of slopes of elevated spoil stacks as well as deep remaining pits not designed to be filled with water the observance of the following principles is suggested:

   - employ the incline of slopes not greater than 1:3
   - employ partitioning of slopes higher than 10 m, with the intermediate shelves of a width 5 - 7 m inclined in the direction to slope above the shelf (to the inside of stack)
   - vertical distances between intermediate shelves should depend on climatic conditions - in a zone of heavy precipitations this distance ought to be decreased even down to 6 m
   - on the flat top portion of the stack by the verge of a slope or a system of slopes have to be formed a counter-slope slanted towards inside of the top area's middle with a decline of 5 %.

4. The top flat areas of the stacks shoul be shaped in a form of gently slanting fields with declines in directions ensuring a gravitational drainage.

5. On the top areas of the stacks greater declines than 5 %, should not be used and only exceptionally on small areas the declines up to 10 % may be permitted. The gradient of the decline should be so selected as to limit to minimum the water erosion.

IV. Reclamation treatments - general recommendations.

1. In the planning and performance of particular reclamation treatments the soil and climatic conditions should be analysed in detail in order to determine the appropriate procedures, machines and equipment and also the best times for such treatments execution. These problems are particularly important in cases of very cohesive soils and soils very permeable.

2. Parallel with the final relief formation of the spoil stacks, also the draining arrangements should be installed.

3. To limit the negative effects of erosion, especially on the slopes of the stacks, the treatments connected with introduction of vege-

tation should be carried out immediately after the completion of final formation of the spoil stacks.

4. All reclamation treatments should be performed with a detailed accuracy and the unsuccessful treatments and the losses in biological cover should be repeated or made up as soon as possible.

5. Include into the reclamation treatments the operations connected with the protection of adjacent terrains against their getting covered with mud washed out from the spoil stack during rainy periods.

V. Neutralization of toxic soils.

1. For the liquidation of excessive acidification two neutralizers are suggested to be used simultaneously:
   - for cohesive soils - agricultural quicklime and ground phosphate rock
   - for sandy soils - magnesia (magnesium oxide) lime and ground phosphate rock.

2. The method of neutralizer introduction should provide possibly its fastest reactions with the soil, and also limit the losses caused by wind and water erosion.

3. Very important from the point of view of neutralization correctness is the application of phosphorus neutralizer as this neutralizer among other things helps to block a considerable amount of iron liberated in the process of weathering on a stack of soils coming from deeper geochemical reducing zones of openpit.

4. Very beneficial is calculation of the neutralizer doses, for the fore designed full liquidation of the electrolytic acidity in the 0-30 cm layer. The computed in this way doses should be increased in order to supply a necessary reserve, required because of the difficulty of reaction of introduced in a solid form neutralizer with toxic substances in soil. Observations carried out in the course of research indicated, that the amount of this reserve depends on climatic conditions (the wetter climate, the less is required - but to certain limits only).

5. The neutralization of soils should be taking place concurrently with the initiating of biological processes. The introduction of pioneering vegetation serves this purpose. It is not excluded that also other type of vegetation could play the part of cooperation with neutralization, as for example a vegetation useful economically, provided if did possess great dynamics of growth (this contention however requires a verification).

6. In order to be able to introduce a pionerring or other vegetation onto the toxically acid soils, necessary is to employ such a dose of neutralizer, as to effect the pH reaction in a few centimeter deep layer, beyond the threshold value, which in the investigated cases probably stays within the 3,0 - 3,5 pH in KCl. The determination of a more precise threshold value requires further experiments.

7. The neutralizer used on the slopes ought to be very active, and in a concentrated form and its doses should effect quick exceeding the threshold value of pH reaction to a deepth, to which seedlings will be introduced, taking into account the inevitable losses caused by erosion.

VI. Mineral fertilization.

1. The amount and composition of fertilizers should be determined on the basis of results of carried out soil examination and the requirements of introduced vegetation, or on the basis of special field tests.

2. The fertilizers should be introduced in few doses, i.e. in a form of initial dose and a completing it fertilization dose outside the roots, so to diminish the losses and to avoid too large concentrations of nourishing compounds during the first phase of vegetation development.

3. For clayey and silty soils, in climatic conditions approaching the investigated, the amount of initial dose can be adopted as follows:

Fertilizers	N -	around	200	kg/ha	in pure	component
"	P -	"	50	kg/ha	"	"
"	K -	"	30	kg/ha	"	"

4. As a complementary fertilization outside the roots, the introduction chiefly of N fertilizers is recommended.

5. Among the to be introduced forms of fertilizers, especially of nitrogenous ones saltpetre forms e.g. ammonium nitrate are recommended. This comes from a fact, that they fulfill additional task of chemical oxidisers, facilitating thus the course of neutralization processes.

VII. Vegetation.

1. Species of vegetation, able to contribute to the process of neutralization, and fulfill the soil reproducing functions should be introduced onto the toxic spoil stacks. They must possess great dynamics of development.

2. On the top portions of the spoil stacks the application of mixtures of papilionaceous plants and grasses composed of the following species is advised:

   - Lupinus polyphyllus
   - Trifolium repens
   - Lotus corniculatus
   - Agrostis alba
   - Lolium multiflorum westerwoldicum
   - Festuca rubra
   - Phleum pratense.

3. In case of employment for neutralization e.g. of ground phosphate rock and ammonia water instead of the ground quicklime, a substantial cut down on the share of papilionaceous plants in the mixture, particularly of Trifolium repens and Lotus corniculatus is advised.

4. In order to inhibit quickly the erosion of the slopes, in the first place the papilionaceous vegetation and grasses should be sown, and trees and shrubs only later in protective cover of these plants.

5. Into the mixtures accompanying the efforestations should be included chiefly the:

   Arrhenatherum elatius
   Festuca rubra
   Phleum pratense - in small quantity.

6. In determining the species of arborescent plants introduced onto the slopes, one should consider the necessity of simultaneous introductions of plants' phytomeliorating, protecting, and biocenotic species, and species for final destination. One should avoid the employment of species not typical of the pertinent climatic .conditions.

7. The density of planting should not be less than 1,5 x 1,5 m.

8. For the planting the reared in nursery material of a high quality should be used.

VIII. Advised further detailed studies.

1. Advisable would be to carry out analogical studies on the territory of U.S.A. in similar soil conditions, but in a climatic zone of low precipitation and higher temperature to widen the knowledge of the role of climate influence on the effects of neutralization and fertilization.

2. It would be useful to carry out specific research studies having for their goal the more accurate determination of threshold acidity value for toxic soils, the attainment of which already promotes the positive results of reclamation.

3. It would be purposeful to carry out special field tests for the determination of an optimum initial dose of mineral fertilizers for the sandy soils.

4. It would be very beneficial to prolong the observation period of the plant development and the changes of soil on experimental plots accomplished in the framework of this study, in order to widen and to specify precisely the acquired results. This bears primarily on the trees and shrubs planted on the slopes.

Fertilizers	N - around	200	kg/ha	in pure	component
"	P - "	50	kg/ha	"	"
"	K - "	30	kg/ha	"	"

4. As a complementary fertilization outside the roots, the introduction chiefly of N fertilizers is recommended.

5. Among the to be introduced forms of fertilizers, especially of nitrogenous ones saltpetre forms e.g. ammonium nitrate are recommended. This comes from a fact, that they fulfill additional task of chemical oxidisers, facilitating thus the course of neutralization processes.

VII. Vegetation.

1. Species of vegetation, able to contribute to the process of neutralization, and fulfill the soil reproducing functions should be introduced onto the toxic spoil stacks. They must possess great dynamics of development.

2. On the top portions of the spoil stacks the application of mixtures of papilionaceous plants and grasses composed of the following species is advised:

   - Lupinus polyphyllus
   - Trifolium repens
   - Lotus corniculatus
   - Agrostis alba
   - Lolium multiflorum westerwoldicum
   - Festuca rubra
   - Phleum pratense.

3. In case of employment for neutralization e.g. of ground phosphate rock and ammonia water instead of the ground quicklime, a substantial cut down on the share of papilionaceous plants in the mixture, particularly of Trifolium repens and Lotus corniculatus is advised.

4. In order to inhibit quickly the erosion of the slopes, in the first place the papilionaceous vegetation and grasses should be sown, and trees and shrubs only later in protective cover of these plants.

5. Into the mixtures accompanying the efforestations should be included chiefly the:

   Arrhenatherum elatius
   Festuca rubra
   Phleum pratense - in small quantity.

6. In determining the species of arborescent plants introduced onto the slopes, one should consider the necessity of simultaneous introductions of plants' phytomeliorating, protecting, and biocenotic species, and species for final destination. One should avoid the employment of species not typical of the pertinent climatic .conditions.

7. The density of planting should not be less than 1,5 x 1,5 m.

8. For the planting the reared in nursery material of a high quality should be used.

VIII. Advised further detailed studies.

1. Advisable would be to carry out analogical studies on the territory of U.S.A. in similar soil conditions, but in a climatic zone of low precipitation and higher temperature to widen the knowledge of the role of climate influence on the effects of neutralization and fertilization.

2. It would be useful to carry out specific research studies having for their goal the more accurate determination of threshold acidity value for toxic soils, the attainment of which already promotes the positive results of reclamation.

3. It would be purposeful to carry out special field tests for the determination of an optimum initial dose of mineral fertilizers for the sandy soils.

4. It would be very beneficial to prolong the observation period of the plant development and the changes of soil on experimental plots accomplished in the framework of this stucly, in order to widen and to specify precisely the acquired results. This bears primarily on the trees and shrubs planted on the slopes.

5. It would be very beneficial to carry out similar studies on selected cereals, root crops and industrial crops on the previously reclaimed terrains and on terrain completely raw, in order to evaluate the influence of reclamation onto the effects of recultivation. A special attention in these investigations should be drawn to the quality of acquired agricultural products.

7. BODY OF REPORT.

7.1. The purpose and scope of research work.

The purpose of the research in a framework of the commissioned subject was elaboration of a complex technical reclamation process for the toxic disposal stacks in the lignite strip mines. The research work was intended mainly to elucidate the problems of neutralization or some other methods to be employed for the elimination of soil toxicity, resulting from the presence and decomposition of the sulphur compounds. The basic sources of toxicity in the Polish lignite strip mines are the iron sulphides, in particular the pyrite, marcasite, pyrrhotite hydrotriolite and possibly some others. On the spoil disposals these compounds are converted biologically and chemically into various substances, which have their direct or indirect toxic effect on the growth of higher vegetation and soil microflora. The composition and the nature of the toxic compounds depend on sulphide concentration and also on the type of formations in which these sulphides occur, in particular on the presence or absence of alkaline compounds.

The most readily detectable evidence of the sulphide toxicity is the strong acidity resulted by the presence of free sulphuric acid and its reaction products with mineral substances of soils deposited in the spoils. One could not exclude, that at least periodically, a toxic effect is exerted by the decomposition products of sulphides appearing in a gaseous form (H_2S, SO_2) in the ground pores. An additional source of toxicity may be the humus compounds contained in the lignite and which may exhibit their chemical or biochemical toxic effect when dissolved in a liquid phase of the ground medium under strongly acid conditions.

Apart from the toxicity of the soils, the air is frequently polluted to a considerable extent with gases and particulate matter derived from the nearby power plant operating on the lignite. This should be allowed for during the designing and accomplishing of operations covering the reclamation and the site planning. Having in mind the above mentioned factors and also the results of tests carried out up to now here and abroad in order to achieve a reasona-

ble elimination of toxicity, the research programme was formulated to cover the following the following scope of problems:

1) elaboration of methods employed to estimate the degree of toxicity occurring in the overburden formations and on the disposal sites,

2) elaboration of methods used to neutralize the toxic soils in spoils and adapted to agricultural and forest restoration,

3) elaboration of a neutralization process for the toxic soils on steep slopes and of detailed principles of their erosion inhibiting biological consolidation,

4) elaboration of a qualitative and quantitative composition of the vegetation initiating the soil forming processes and actively cooperating in a biological neutralization of the toxic formations,

5) determination of suitable agricultural methods for the reclamation operations,

6) elaboration of instructions for the overburden management in order to eliminate or to reduce the toxicity, through the deconcentration of formations which exhibit such properties.

The program of studies was determined with an allowance for a short period only, as for the biological research; namely a three years' period was provided for the implementation of the job. In order to lessen the inconvenience which thus affects the reliability of research it was decided to widen the experimental work on a greater number of repetitions.

7.2. A detailed program of research.

The basic assumptions for the provided research program were following:

1. It was decided to accomplish the task on the basis of research and field experiments results carried out with material examined in detail in a laboratory.

2. It was decided to accept the following objects for examination:

   1) the top portions and the slopes of disposal stacks, of various exposures,

   2) the loamy and sandy soils,

   3) the weakly toxic and the very toxic soils.

3. The soils were neutralized by means of:

   1) agricultural ground quicklime (CaO)

   2) ground phosphate rock

   3) ammonia water

   4) magnesium oxide lime (CaO, MgO), a waste product of the zinc manufacture.

4. It was decided to test the effectiveness of neutralizers in various combinations and amounts adapted to the results of laboratory and biological tests.

5. It was decided to check the usefulness and the agricultural conditions for an application of one layer or two layer neutralization in the top portions.

6. It was decided to apply uniform doses of phosphatic and potassic fertilizers, but two different doses of nitrogeneous fertilizers.

7. It was decided to test the effectiveness of four different mixes of Papilionaceae with grasses introduced onto the topsolis and to apply a uniform universal mix on the slopes with various methods of sowing.

8. It was decided to test on the slopes the effectiveness of a dozen of varieties of trees and bushes applied in various sets of species and also various methods were used for the preparation of surface for implantations.

According to the assumed research program the following operations were to be performed:

1) selection of experimental plots on the basis of field and laboratory research work carried out;

2) preparation of a pedological specification for the experimental plots;

3) setting up of experimental plots;
4) execution of basic agrotechnical treatments on plots, including the treatment with neutralizers and fertilizers;
5) sowing of papilionaceae - grass mixes;
6) planting of trees and bushes;
7) cultivation operations' execution;
8) pedological tests performance;
9) to carry out observations and biometric measurements of vegetation.

The operations mentioned in points 1 to 5 were executed in the first phase of operations provided in agreement for the year 1973, the mentioned in point 6 were performed in the second phase, i.e. in the year 1974, and the operations named in points 7-9 were accomplished successively in the II and in the III phase, i.e. in the year 1974 and 1975.

7.3. General description of the "Turów" lignite strip mine.

The "Turów" strip mine of lignite is situated in the south - western part of Poland in the Region of Jelenia Góra and is now the largest openpit mine in Poland.
The strip mine of lignite, "Turów", was founded on a deposit of lignite of the same name. The excavation is carried out in two open pits called Openpit mine Turów I, and Openpit mine Turów II.

7.3.1. The geological structure.

This deposit is located in a basin whose floor and frames are formed from paleozoic crystalline rocks mostly from granites and granite-gneisses. Moreover, in the basin's bottom and on its periphery basalt intrusions of tertiary age are being found sometimes. In this trough on the bedrock a complex of tertiary sediments occurs, covered by quaternary formations.
The lithological profile of the Tertiary series could be represented as follows:

- floor series - clayle sediments with sandy intercalations in the form of lenses. The thickness of this series varies from few maters in the peripheral part to 80 m in the central part,
- bottom lignite seam (I) - maximum thickness 20-30 m, and average thickness more than 12 m,
- the series between the seams - clayle series with lenses of sands and gravels. The thickness of this series varies from 20 to 100 m, on average about 30 m,
- the top lignite seam (II and III) - is partly continuous and partly separated to benches. In the continous part its thickness varies from 60 to 100 m in the basin's center, and up to few meters on the periphery. An average thickness of the seam II is about 20 m, and of the seam III about 18 m,
- the roof series - is formed of clays in which the lenses of sands, of gravels and of lignite occur. The thickness of this series varies from 80 to 140 m.

The series of the Tertiary period are covered with quaternary formations represented by the boulder clays, the loesslike clays, sands and gravels. The thickness of quaternary formations is variable, but it does not exceed 20 m.

As we can see the overburden of the Turów lignite deposits constitutes complex of the tertiary and quaternary clayly-sandy-gravel formations. It attains a maximum total thickness of 180 m on the area of strip mines "Turów I" and "Turów II". The tertiary series constitutes about 80-90 % of the entire mass of overburden rocks. Prevailing in this series are clays. However, the sands appear in lenses of varying horizontal dimensions and thicknesses from 0,5 to several meters. These are the medium and coarse grained sands built of weakly pebbled silica and white chippings of weathered feldspars as well as scarce amounts of lyolite chippings and metamorphic rocks. They contain a large addition of white, clayly binder with no lignite fragments.

The main bulk of tertiary clays is characterized by a grey - green colour, no stratification, fine scattered vegetable detritus and the presence of large lignite fragments. Sanding up varies conside-

rably. The sandy material is analogical to that occurring in lenses. The tertiary series contains also dark carbonaceous clays. They form thin continuous benches, where numerous trunks and wood roots are observed. The carbonaceous clays are stratified horizontally with a coarse vegetable detritus comprising high content of leaves. Towards the roof, in the partially carbonized tertiary series, an increase in the sand contents is observed. The tertiary formations appearing on the surface or at a small depth in the roof portion are rust-coloured. Between the Turów I and Turów II strip mines, the above tertiary series is covered with a dozen meters thick complex of quartz gravels forming a local elevation. These gravels contain an addition of white, silty parts and numerous kaolinated feldspars. Their macroscopic composition is analogical to that of the tertiary sands described.

In the west part of the Turów II strip mine near the Nysa Łużycka river-bed, the tertiary rocks are covered with pleistocene sediments. These are the rust-coloured gravels with large amounts of Scandinavian rock chippings, well classified fine - and medium grained quartz sands and also white and rust - coloured silts. The sands and gravels are covered with a several meters thick layer of clays and silts, which exhibit a dense horizontal lamination.

From the overburden of Turów I and Turów II strip mines samples of soil were taken for the analyses in order to characterize qualitatively the particular formations. Owing to the different form of occurrence, different sampling methods for tertiary and quaternary rocks were adopted. Samples of tertiary rocks were taken for particular lithological varieties from a few scores of points on all horizons of the overburden, disregarding the weathered zone.

The quaternary rocks and quartz gravels in compact masses and therefore a groove or point method of sampling at regular intervals was applied to them, and perpendicular to the stratification if possible. The results of studies on the samples representing particular series of the overburden formations are presented on Tables 1-3. A shortened mineralogical, chemical and agricultural characteristic of the samples examined may be described as follows:

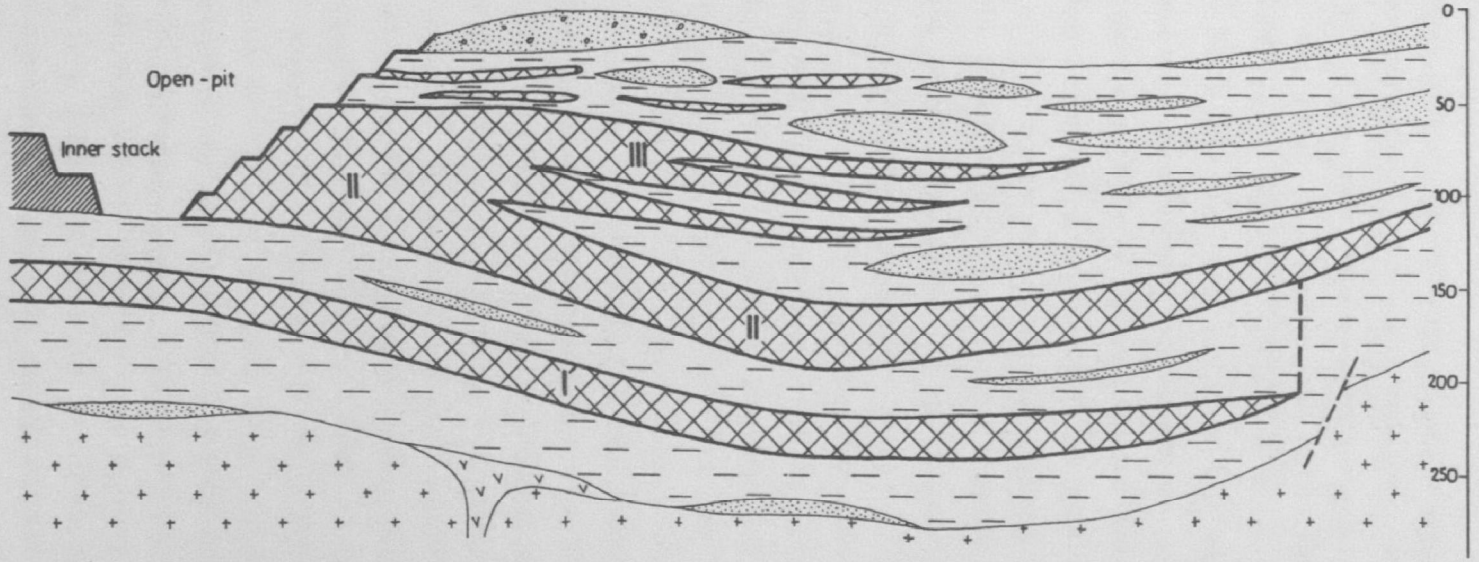


Fig. 1. SCHEMATIC N-S SECTION OF TURÓW LIGNITE BASIN

1) Quaternary silts and clays.

These formations are dark-grey with evident parallel stratification. The 0.025 mm fraction makes 64 % and consists mainly of quartz and small amounts of feldspars and mica. The feldspars are partially weathered. The silty fraction contains mainly kaolinite and illite group minerals. The illite content increases in the intermediary fraction (0.006 - 0.026 mm). Low phosphorus content, medium potassium content, low sulphur content (0,15 %).

2) Quaternary sands and silts.

The main component of these formations is quartz which is accompanied by a large amount of feldspars (ortoclase, acid plagioclases and muscovite). Radiographical analysis discovered the presence of a partly recrystallized vitreous substance. In the 0.025 mm fraction, whose content is only 3 %, mainly illites and some kaolinite are accumulated.

3) Rust - coloured quaternary gravels

These formations contain large amounts of larger rock chippings (granites, gneisses). The coarse grained fraction consists mainly of quartz with considerable additions of fieldspars and mica. Among the feldspars both the potassium varieties (microcline, orthoclase) and the sodium-calcium varieties (acid plagioclases) were found to appear. Radiographical analysis discovered the presence of relatively large amounts of vitreous substance, partly devitrified. The 0.025 mm fraction consists mainly of illite and smaller amounts of kaolinite, Ca - montmorillonite and chlorite. Low phosphorus content, medium potassium content.

4) Tertiary quartz gravels.

The main mineral component of these formations, which contains considerable amounts of coarse grained sand is quartz. It is accompanied by smaller quantities of feldspars (orthoclase and plagioclases) and also some muscovite. A weakly crystallised

vitreous substance was also found to appear. The 0.025 mm fraction which makes about 6 % of the sample, contains mainly kaolinite and illite. Low phosphorus and potassium contents.

5) Tertiary carbonaceous clays

These clays, rich in vegetable detritus, have a dark brown colour and distinct stratification. The 0.025 mm fraction which makes 40 % of the sample, consists mainly of quartz, which is accompanied by smaller amounts of muscovite and trace amounts of fieldspars. The clayle fraction consists mainly of kaolinite and small quantities of minerals from the illite and mica group. This formation may be generally defined as a sandy kaolinite clay with some mica and illite group minerals. Low phosphorus and potassium contents.

6) Tertiary clays

These are clayly formations of varying colours - from cream yellow to light brown, non-stratified, containing some vegetable detritus. The 0.025 mm fraction whose percentage is about 27 % is built mainly from quartz and micas - above all muscovite and to lesser extent from weathered biotite. Feldspars appear only in small quantities. The main component of the clayly fraction is kaolinite accompanied by the illite group minerals. In general, one could say that it is a sandy kaolinite clay with large admixtures of the mica and illite group minerals. Low phosphorus content, medium potassium content.

7) Tertiary sandy clays.

These are clayley formations with different degress of sanding up. The 0.025 mm fraction is about 50 % and its main component is quartz. It is accompanied by small quantities of weathered feldspars and micas. On the basis of x - ray pictures however, one may conclude that apart from the above - mentioned crystalline components, there are many substances of a poorly ordered internal structure - this is undoubtedly partly recrystallized glaze. The clayle fraction consists mainly of kaolinite and small quantities of illite the ratio of kaolinite to illite decreases with the

SOME PHYSICAL AND CHEMICAL PROPERTIES AS WELL AS RECULTIVABILITY OF THE OVERBURDEN FORMATIONS IN THE TURÓW LIGNITE STRIP MINE

Table 1

Sample No.	Type of formation	pH		% fraction of dia. in mm					$CaCO_3$ content %	Methylene blue sorption mval BM	Consistency limits			Swelling %	Swelling humidity %
		H_2O	KCl	1,0	1,0 - 0,1	0,1 - 0,05	0,05 - 0,002	0,002			L_s	L_p	L_y		
	Quaternary period														
285	Silts and clays	6,2	5,8	0	7	4	69	20	0,0	8,6	24,2	25,8	41,7	8,2	52,2
284	Sands and silts	6,5	5,4	6	76	11	7	0	0,0	1,1	-	-	-	-	-
283	Rust-coloured gravels	5,6	4,8	84	11	1	2	2	0,0	7,6	-	-	-	-	-
	Tertiary period														
282	Quartz gravels	5,7	5,1	60	30	1	5	4	0,0	2,5	-	-	-	-	-
281	Carbonaceous clays	4,4	4,0	0	9	5	61	25	0,0	9,6	23,6	28,9	49,5	4,4	56,4
280	Clays	5,0	4,4	0	2	7	55	36	0,0	9,6	18,7	19,7	45,3	5,4	46,7
279	Sandy clays	4,8	4,3	2	21	7	41	29	0,0	4,6	18,7	19,4	36,4	3,1	40,9
278	Sands	3,2	3,0	5	81	5	6	3	0,0	1,6	-	-	-	-	-
276	Clays/bed III/	5,0	4,4	0	10	2	41	45	0,0	9,6	24,9	31,0	52,2	4,8	56,4

SOME CHEMICAL PROPERTIES OF THE OVERBURDEN FORMATIONS IN THE TUROW LIGNITE STRIP MINE

Table 2

Sample No.	Type of formation	Total contents of components in %												Contents of components soluble in 20 % HCL in %						Contents of assimilable parts mg/100 g	
		SiO_2	Al_2O_3	TiO_2	Fe_2O_3	FeO	MnO	P_2O_5	MgO	CaO	Na_2O	K_2O	SO_3	Na_2O	K_2O	MgO	CaO	Fe_2O_3	P_2O_5	K_2O	P_2O_5
	Quaternary period																				
285	silts and clays	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	0,02	0,12	0,09	0,42	2,92	0,05	11,5	1,0
284	sands and silts	80,12	8,39	0,75	1,56	0,53	0,02	0,01	1,74	0,27	0,80	2,63	0,15	0,01	0,02	0,04	0,08	0,51	0,01	2,5	0,5
283	rust-coloured gravels	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	0,02	0,09	0,08	0,44	2,90	0,08	10,3	0,7
	Tertiary period																				
282	quartz gravels	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	0,00	0,02	0,03	0,09	0,43	0,01	5,8	0,3
281	carbonaceous clays	50,24	25,42	0,75	0,00	1,76	0,01	0,02	1,71	0,35	0,71	1,70	0,45	0,01	0,05	0,07	0,34	0,69	0,02	9,8	0,6
280	clays	54,26	27,86	1,40	0,34	1,46	0,01	0,02	0,75	0,37	0,19	2,40	0,41	0,01	0,05	0,13	0,21	0,51	0,02	10,8	0,8
279	sandy clays	62,55	21,91	1,15	1,07	0,88	0,01	0,02	0,51	0,40	0,21	2,97	0,39	0,01	0,05	0,10	0,16	0,46	0,02	8,0	0,6
278	sands	84,54	7,33	1,10	0,00	0,51	ślad	0,01	0,20	0,11	0,21	4,12	0,26	0,00	0,02	0,03	0,11	0,19	0,01	2,0	0,2
276	Clays/bed III/	46,80	32,21	0,13	0,00	1,78	0,03	0,03	0,54	0,24	0,17	1,55	0,37	0,02	0,04	0,06	0,21	0,72	0,03	19,0	0,7

n.o. = not determined

APPROXIMATE CONTENTS OF TRACE ELEMENTS IN THE OVERBURDEN FORMATIONS OF THE TURÓW LIGNITE STRIP MINE

Table 3

Sample No.	Type of formation	Mn	Ni	Cr	B	Ba	Sr	Ga	V	Cu	Co	Be	Zr	Sn	Po
	Quaternary period														
285	silts and clays	I	I	I	I	II	I	I	I	$	$	$	S	-	-
284	sands and silts	I	S	S	I	II	I	S	I	$	-	-	S	-	$
283	rust-coloured gravels	I	I	S	S	II	I	S	I	$	$	$	S	-	-
	Tertiary period														
282	quartz gravels	I	I	I	S	II	I	I	I	$	-	$	S	$	S
281	carbonaceous clays	I	I	I	I	II	I	I	I	$	/$	S	S	S	S
280	clays	I	I	S	I	II	I	I	I	$	-	S	$	$	S
279	sandy clays	I	I	I	I	II	I	S	I	$	$	S	S	S	S
278	sands	I	S	S	$	II	I	S	S	$	-	-	S	-	S
276	clays /bed III/	I	I	I	I	II	I	I	I	$	$	S	S	$	S
Detectability in % by weight		0,01	0,001	0,001	0,001	0,001	0,001	0,0003	0,001	0,0001	0,001	0,0003	0,001	0,0003	0,001

Explanations

II element appearing in percentages from 0.1 to 0.01 %
I element appearing in percentages from 0.01 to 0.05 %
S element appearing in percentages from 0.05 to 0.001 %
$ element content on the identification limit
- below identification limit

increasing grain size. The formation in question may be generally defined as a very kaolinite - illite clay. Low phosphorus and potassium contents.

8) Tertiary sands.

These are coarse grained sands and gravels with chippings of montmorillonite. The fraction above chippings of montmorillonite. The fraction above 0.025 mm makes up to 97 % and consists mainly of quartz, small quantities of weathered micas and feldspars (mostly plagioclases) and vitreous substances, similar to the above mentioned sandy tertiary clays. This might explain a high K_2O content, in spite of relatively low quantities of micas and feldspars. The main component of the fraction below 0,025 mm is kaolinite. It is accompanied by smaller quantities of illite. Low phosphorus and potassium contents.

9) Tertiary super - and intercarbonaceous clays.

These are clayly formations of varying colours - from cream yellow to brown, non-stratified. The main component of their mineralogical composition is kaolinite which appears as a main component of the fraction below 0,006 mm and is accompanied by smaller quantities of illite and quartz. Kaolinite also enters into the composition of the intermediate fraction 0,006 to 0,025 mm. The fraction below 0,025 mm contains mainly quartz, apart from some quantities of micas (miscovite and biotite) and also of fieldspars. Both biotite and feldspars demonstrate distinct manifestations of weathering. On passing from fine to coarser fractions the content of kaolinite decreases and that of illite and micas increases. In general, these rocks may be described as somewhat sandy kaolinite clays with large additions of the mica and illite group minerals.
Low phosphorus content, medium potassium content (fringing upon the high content).

7.3.2. Technology of extraction operations.

Owing to a considerable depth of the strip mine the working of overburden and coal is being carried out along the walls, to a height

corresponding to the working reach of the excavators. The excavators work the wall from a so called working level, on which situated are also systems transporting the worked out masses by the excavators. The overburden is being hauled to the site of its disposal - onto a so called spoil disposal stack, and the coal to the consignees, of whom the main one is the power plant situated nearby the strip mine.
The total depth of the openpits in now about 180 m and will reach in future about 250 m. So the advance of the pits is horizontal and vertical simultaneously.

The strip mine Turów I.

On the strip mine Turów I, bucket wheel excavators are working. The hauling of the winning on 3 higher working horizons is being accomplished by means of belt conveyors, and on lower horizons by railway. The lignite is being extracted only on the lower horizons consequently it is transported with trains directly to the consignee or to the lignite sorting plant, or to the lignite reloading point where with the aid of reloading appliances is delivered on to the belt conveyors supplying the power facilities with lignite. The overburden worked on the horizons and transported on belt conveyors is being directed through the inclined drifts onto the main overburden belt conveyors, connecting the strip mine Turów II with an external spoil disposal. The overburden worked on horizons furnished with a rail transportation system is being delivered to so called reload trenches, whence with the aid of reloaders is fed onto the system of belt conveyors, and transported by way of collecting belt conveyors on the external disposal. Insignificant only portion of overburden coming from the lower levels is led directly onto an internal spoil disposal.

The strip mine Turów II.

On the strip mine Turów II bucket wheel excavators are used. The transportation of the winning proceeds only by means of belt conveyors. The winning of particular excavators carries away horizontal travelling coveyor belt, and delivers it to the inclined drift where with the aid of mobile transfer conveyor belts is being directed

respectively onto the continuous conveyor belts for lignite or for overburden. Lignite is being transported with the system of conveyor belts to the power plant, and the overburden is carried away on the collecting conveyors onto the external disposal stack jointly with the overburden delivered there from the strip mine Turów I.

The external spoil stack.

Presently the overburden is being stacked almost entirely on the external stack, which will be in operation until there will be extracted enough lignite from the seams I and II. After that the overburden will be stacked wholely on the inner stack.
On the external disposal there is stacked also with the overburden the fly ash generated in the power plant. It is being fed with the system of ash belt conveyors and poured onto the overburden belt conveyors, prior to their entering the overburden distribution station, localized on the disposal. An average ash content in raw lignite amounts to 10 %, and in dry lignite 20 %.
A joint stacking of ash together with the spoil of overburden, as the performed research had indicated, improves the stability of the disposal stack's slopes provided there is an uniform distribution of ash in the bulk of the stack. Formation of continuous ash layers gives negative effects in this respect, as such layers are sliding, and endanger the stability of the stack slopes. On the outer disposal there are working stackers. Each stacker is connected by means of conveyor belts to the overburden distribution station.

The stackers are working on the so called working levels, from which are formed two layers of the stack:

- the under stacker layer - below the working level
- the over stacker layer - above this level.

From a practical point of view there are being adopted following heights for these layers, in the Turów surface mine:

for the over stacker layer 20 m
for the under stacker layer 30 m.

The external disposal will be developed initially on its level, later on after filling of a determined area, there will be formed higher

levels with the aid of the same stacking machines.
By the described above system about 20 milions tons of lignite and 70 milions cubic meters of overburden is removed every year. So then in the effect of excavation operations three kinds of post-industrial terrains will occur:

- the external disposal - of an area about 3000 ha and an elevation above the adjacent land about 320 m,
- the internal disposal - of an area about 1000 ha, and an elevation formation approximated to the natural profile of the terrain,
- the final excavation of an area about 1700 ha of a maximum depth about 250 m.

PAGE NOT

AVAILABLE

DIGITALLY

7.4. Report of research carried out on the experimental plots set up on the external disposal stack, of the Turów strip mine.

The detailed investigations were localized on the experimental plots set up in the south-western part of the external disposal of the "Turów" mine, raised above the surrounding terrain by some 70 m. The habitat conditions of the selected fragment are representative of the entire disposal. The portion of the disposal on which the plots were established has completed its formation and so the investigations and observations can be performed for any length of time at one's discretion. The location of the plots and the relief formation of this part of the disposal is shown on the fig. 3. The localization and the formation of the plots is being considered as advantageous for the performed research effort mainly on account of hard conditions caused by the elevation of this part of the disposal and the relative closeness to the power plant constituting a main source of atmospheric pollution.

7.4.1. Charaterization of the habitat conditions on the experimental plots.

7.4.1.1. Characterization of the soils.

The soils appearing in the disposal and also on the experimental plots form a mixture of previously described overburden formations. The predominant material in the surface layers are the tertiary clays with some sands and gravels. A characteristic feature is the variability of the composition and properties of surface layer formations on the disposal site, both vertically and horizontally. This is related to the stripping, transport and stacking processes of the very lithologically differentiated overburden rocks. In this area toxicity increases with the increasing contribution of carbonaceous tertiary clays in the bulk of soils appearing in the surface layers of the disposal.

In order to prepare the pedological, chemical and agricultural documentation of the disposal site, 61 test pits were made and 107 samples were taken, employing the following sampling technique:

a) from parts differing in their position (disposal top, upper and lower portions of slope, the interslope shelf);

b) from all surfaces differing in their macroscopic grain composition, contents of lignites and xylites;

c) from slopes of different exposures.

Generalized results of laboratory examination are given on the Table 4. These results show, that the Turów mine disposal site and in particular the fragment designed for experimental plots, possesses the formations, whose features are not favourable to the growth of vegetation. The main reason is the strongly acid reaction - even toxic in some places, its stepwise variability and defective physical properties of the material deposited there.
One of the criteria to estimate the biotopic conditions of soils to be recultivated is the state of vegetation, stemming from natural succession. The occurrency of various species of plants or their absence indicate good or poor chemical, physical and biological properties of the soil.
Several phytosociological pictures were made by the Brown-Blanquet method on the surface assigned for the experimental plots. Although 7 years passed from the moment of erection of this disposal, the vegetation stemming from natural succession covered only about 0,5 % of the entire surface.

Three species were mostly in evidence:

- Calamagrostis opigeios
- Agrostis vulgaris
- Tussilago farfara.

Apart from these species there were some others fewer in numbers, sometimes just few specimens:

- Equisetum arvanse
- Rumex acetosella
- Rumex crispus
- Rumex obtusifolius
- Polygonum aviculare
- Polygonum persicaria

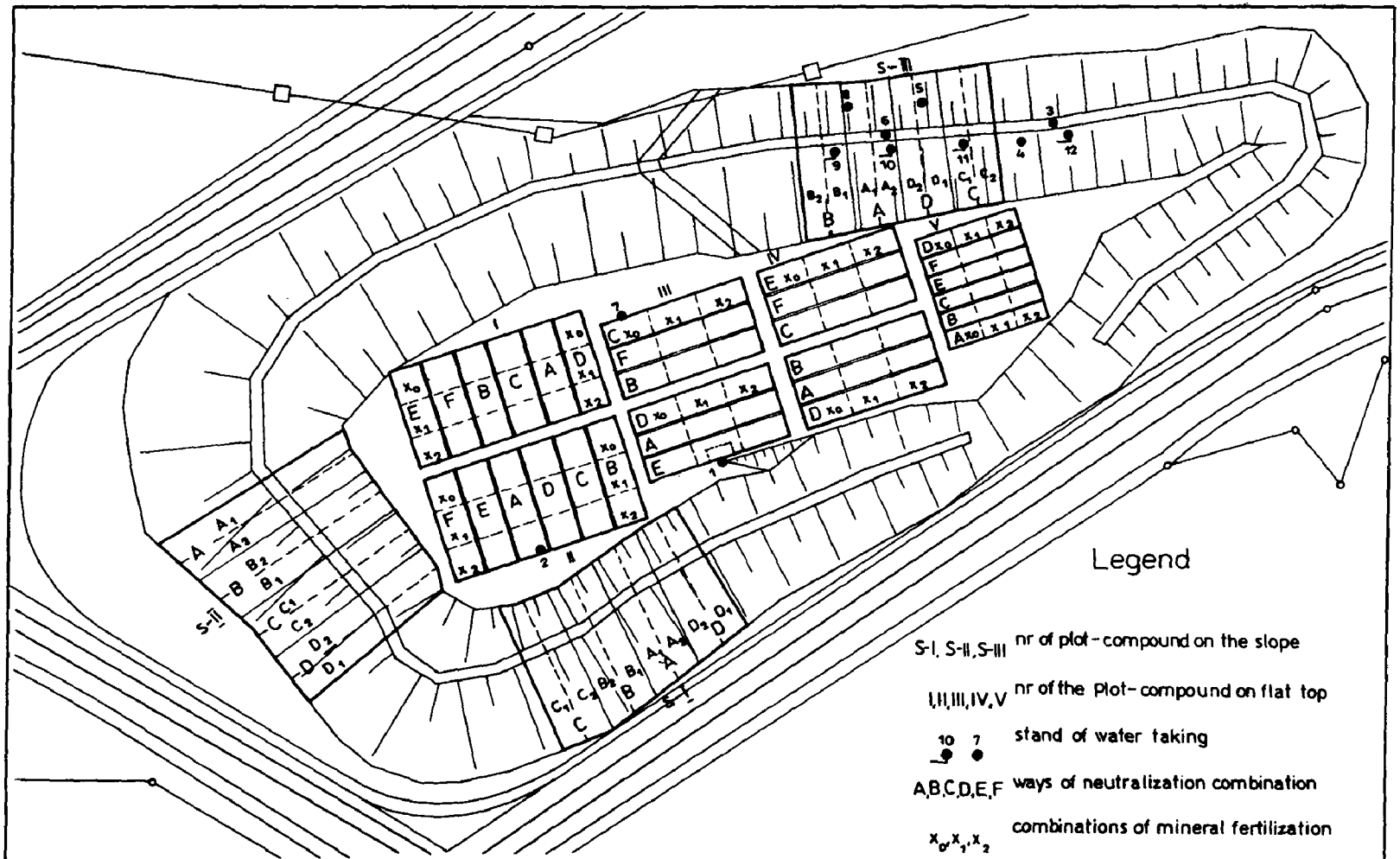


Fig. 3 Plan of experimental working plots of the lignite mine „Turów"

RESULTS OF ANALYTICAL STUDIES ON GROUNDS FROM EXPERIMENTAL PLOTS IN THE DUMPING GROUND OF THE TUROW LIGNITE STRIP MINE

Table 4

Designation	Unit	from	to	Average	Notes
Skeleton content dia. below 1 mm	% by weight	0	51,6	0 - 10	
Organic matter content (lignites, xylites)	% by weight	0	8	0 - 2	
Content of particles					
0,05 ϕ 1	% by weight	83	88	85	in gravels and sands
0,05 ϕ 1	% by weight	15	74	30 - 40	in clays and silts
ϕ 0,002	% by weight	6	9	7	in gravels and sands
ϕ 0,002	% by weight	10	37	20 - 30	in clays and silts
Liquid limit L_y	% by weight	25	58	30 - 40	in clays and silts
Yield point L_p	% by weight	16,8	45	20 - 25	in clays and silts
Contraction limit L_2	% by weight	15,0	39	20 - 25	
Plasticity index W_p	% by weight	5,5	22,1	13 - 18	
Swelling	% by volume	1,3	6,0	2 - 4	
Swelling humidity	% by weight	25	65	35 - 45	
Reaction in H_2O	pH	3,2	6,6 x/	4,0 - 5,0	x/ higher values of pH apply to samples with high ash percentage
in KCl	pH	3,0	5,7 x/	3,5 - 4,5	
Hydrolytic acidity H_h	mval/100 g	0,5	16,6	9,0	
Exchange acidity H_w	mval/100 g	0,08	1,56	0,1 - 0,5	
Exchange aluminium Al_w	mval/100 g	0,0	3,90	1,0 - 2,0	
Total S including:	% by weight	0,1	1,0	0,4 - 0,6	
SO_4^{2-} - as salt	mg/100g	16	116	80	
SO_4^{2-} - as free H_2SO_4	mg/100g	2,9	8,2	4,9	
Components soluble in 20 % HCl					
Na_2O	% by weight	0,01	0,04	0,01	
K_2O	% by weight	0,02	0,10	0,03	
MgO	% by weight	0,01	0,05	0,02	
CaO	% by weight	0,01	0,05	0,02	
Fe_2O_3	% by weight	0,56	2,53	0,6 - 1,1	
P_2O_5	% by weight	0,02	0,04	0,03	
Components assimilable by the plants					
K_2O	mg/100 g	5,7	55,0 x/	9 - 14	x/ content below 40 mg/100 g only in one sample
P_2O_5	mg/100 g	0,1	1,4	0,4 - 0,5	
C - total x/	% by weight	0,12	2,86	0,6 - 1,0	x/ determined after discarding chippings of lignites and xylited
N - total	% by weight	0,01	0,10	0,05 - 0,08	
C/N		7,3	32,8	10 - 20	

- Achillea millefolium
- Holcus mollis
- Symphytum officinale
- Poa compressa
- Chamaenerion angustifolium.

A small number of specimens and vegetable species confirm the thesis on conditions being unfavourable to the growth of vegetation, based on the results of laboratory analyses.

7.4.1.2. The characteristics of atmospheric precipitations.

The characteristic of atmospheric precipitations was prepared on the basis of observations carried out in the meteorological station located 2 km toward south.
Compiled on the table below are the monthly and yearly sums of average and extreme precipitations for the period of years 1947 - 1972 and also monthly and yearly precipitation sums for years 1973, 1974 and 1975.
Moreover, the daily distribution of precipitations during the time of carried out investigations is marked on the "Comprehensive diagram of treatments and observations".
From the compiled on the table values a particular attention draw dry periods, which had a substantial influence on the growth of plants. These periods occurred during the following fixed times:

year 1973 - August and September
year 1974 - March and April
year 1975 - August and September.

A typical characteristic of the precipitations during these periods were the heavy daily precipitations, and only very few days with precipitation. Such a form of precipitation occurrence and the simultaneous high temperatures of air, as for the Polish conditions caused a halt in the vegetation development, especially so with the grasses. The periods with the significantly increased precipitations occurred in 1974 - in months May, June, August, October, and December, and in 1975 in July on the turn of the second and third ten day periods

and had no negative influence on the growth of plants, because, as already mentioned, had a character of short - duration precipitations of great intensity. In the remaining periods the amount of precipitations fluctuated closely to the long term average values.

Specification of typical values of precipitations recorded by the meteorological station Bogatynia

Table 5

Period 1 year	Monthly precipitations in mm	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
From the period 1949-72	Average	34,3	39,0	38,5	57,5	79,5	84,9	95,4	74,4	57,5	48,2	39,6	44,7	693,5
	Maximum	75,8	99,7	81,0	108,8	170,0	192,0	197,9	150,8	218,7	136,5	75,3	97,8	930,1
	Minimum	7,3	11,9	12,0	10,7	27,5	13,1	25,1	35,6	1,9	2,8	3,6	5,9	479,2
1973	Sums	15,0	48,5	22,9	76,6	72,4	54,9	139,1	49,7	18,6	56,6	41,9	30,3	626,5
1974	Sums	22,7	31,4	18,4	8,6	141,5	133,0	87,0	115,9	52,0	152,3	56,8	121,3	940,9
1975	Year	55,2	15,9	31,4	40,3	63,1	91,6	138,0	62,4	22,5	45,4			

7.4.1.3. The characteristics of air temperatures.

The characteristic of air temperatures was prepared on the basis of observations carried out in the station in Zgorzelec, located at a distance of some 30 km from the experimental plots. Compiled on the table are the long - term monthly average temperatures of air and also the averages for particular months and years of 1973, 1974 and 1975. Marked on the comprehensive diagram of treatments and observations are also the average daily values of temperatures. In comparison with average values the period of carried out investigations had warm winter, colder than usual early spring, colder summer period, with exception of the months July, August, September in 1975, in which months the average temperature was plainly higher than the average long - term values.

7.4.1.4. Characteristics of the atmospheric air pollution.

In the region of the mine and the power plant Turów, there are conducted continuous observations of the dust fall out and of the SO_2 concentration in the air by the specialistic Sanitary - Epidemiological Station. The experimental plots are situated very close to the observation posts. The results of observations for the period of years 1973 - - 1975 are compiled on the table no. 7.

Specification of characteristic values for the Zgorzelec Station

Table 6

Month / Average temperature in °C, in years	I	II	III	IV	V	VI	VII	VIII	IX	X	X	II	Year
1949 - 1972	- 1,8	- 8,0	1,7	8,0	12,3	16,2	17,5	16,7	13,4	8,7	4,1	0,1	7,4
1973	- 0,4	- 1,6	3,9	5,0	12,5	15,2	17,1	17,0	14,7	7,0	2,9	-0,3	7,5
1974	2,5	2,6	5,5	7,0	10,8	14,1	15,7	17,5	13,5	5,6	4,5	4,1	8,6
1975	4,0	- 0,2	3,9	6,7	12,3	15,0	18,3	18,2	16,2	7,8			

Specification of results of dust fall out and of SO_2 concentration tests in the air.

Table 7

Month		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Stand	Year	Monthly dust fall out in t/km2/month.												
Lignite Surface Mine Turów	1973	104,7	10,9	65,1	78,6	46,7	25,5	47,8	19,0	18,4	24,0	42,4*	26,2	509,3
	1974	41,7*	42,5	66,6	29,1	53,3	39,3	26,6	73,2	32,9	19,7	32,9	42,3	500,1
	1975	20,4	27,1	9,7	4,7	20,0	39,8	31,4	35,7	21,3	24,9*	37,6	24,9*	298,4
Bogatynia - sewage - treatment plant	1973	43,3	30,2	22,0	82,9	14,6	33,6	26,1	16,5	18,3	25,0	29,3*	10,2	352,0
	1974	30,9	8,0	26,3	11,4	35,1	12,9	27,8	54,3	14,5	22,6	40,2	20,2	304,2
	1975	13,8	15,3*	16,0	10,7	3,7	23,7	21,3	10,6	18,6	18,8	15,4	15,3*	183,2
		SO_2 concentration in the air in mg/m^3												
Lignite Surface Mine Turów	1973	0,166	0,112	0,136	0,132	0,078	0,082	0,056	0,039	0,061	0,130	-	0,218	
	1974	0,156	-	0,037	0,022	0,040	0,047	0,100	0,035	0,036	0,042	0,058	0,061	
	1975	0,055	0,048	0,031	0,004	0,064	0,292	0,059	0,052	0,037	0,152	0,154		
Bogatynia - - sewage - treatment plant	1973	0,167	0,129	0,125	0,131	0,056	0,047	0,039	0,033	0,056	0,115	-	0,174	
	1974	-	0,121	0,068	0,010	0,050	0,056	0,081	0,035	0,022	0,044	0,039	0,072	
	1975	0,049	0,067	0,018	0,032	0,051	0,189	0,036	0,027	0,057	0,057	0,074	0,088	

* - the sample was destroyed, adopted for the table were averages from the remaining months

7.4.2. Reclamation operations.

7.4.2.1. Neutralization.

Basic treatments from the scope of neutralization of excessive soil acidification were performed in June - July of 1973 year. As the neutralizers three substances were used, in differentiated doses and combinations:

1) agricultural fertilizer lime, burnt, ground - CaO,
2) ground phosphate rock with content of $CaCO_3$ 40 % and P_2O_5 30 %,
3) ammonia water 25 %.

On the plots localized on the top portion of the disposal stack the following combinations of neutralization were employed:

A - without neutralization control (plots) 15 plots of a total area 0,36 ha

B - CaO in doses 5 tons/ha, in one layer 15 plots of a total area 0,36 ha

C - CaO in doses 10 tons/ha in two layers:

0 - 15 cm	5 t/ha
15 - 30 cm	5 t/ha

15 plots of a total area 0,36 ha

D - CaO in doses 5 t/ha and ground phosphate rock in doses 3 t/ha, in two layers:

0 - 15 cm	5 t/ha CaO
15 - 30 cm	3 t/ha of ground phosphate rock

15 plots of a total area 0,36 ha

E - ground phosphate rock in doses 3 t/ha, in one layer, 15 plots of a total area 0,36 ha

F - ground phosphate rock in doses 3 t/ha and 25 % ammonia water in doses 5 cu.m/ha in one layer,

15 plots of a total area 0,36 ha.

Therefore the experimental area on the top portion of the disposal comprized 90 plots, of a total area 2,16 ha (fig. 3).

The introduction of neutralizers necessitated the performance of following tillage operations:

1) Done twice scarification with cultivator of entire experimental area, i.e. of 90 plots of a total area 2,16 ha.

2) Spreading of ground phosphate rock in doses 3 t/ha on 45 plots of the D, E, F combination, of total area 1,08 ha.

From these data transpire the following general conclusions:

- the air pollution in this area is significant
- the pollutions are lower than the permissible standards for protected areas, which are obligatory in Poland
- during the period of time of pollutions' investigations, these were at a decrease.

3) Spreading of ground, burnt agricultural fertilizer lime in doses 5 t/ha on 30 plots of the B, C combination of a total area 0,72 ha.

4) Twice done tilling with a rototiller of 75 plots of the B, C, D, E, F of a total area 1,80 ha.

5) Ploughing of 30 plots of C, D combination of a total area 0,72 ha.

6) Spreading of ground, burnt, agricultural fertilizing lime in doses 5 t/ha on 30 plots of the C, D combination, of a joint area 0,72 ha.

7) Pouring of ammonia water, 25 % solution, in doses 5 m^3/ha on 15 plots of the F combination, on a total area 0,36 ha.

8) Twice done tilling with a rototiller of 45 plots of C, D, F combination of a total area 1,08 ha.

9) Harrowing of the entire experimental area, i.e. of 90 plots of a total 2,16 ha area.

On the plots set up on the slopes, 3 combinations of neutralization were adopted:

A_1A_2 - without neutralization (control plots)
6 plots of a total area 0,55 ha

B_1 - CaO in doses 5 t/ha on the surface
3 plots of a total area 0,275 ha

B_2 - CaO in doses 5 t/ha superficially and into pits
3 plots of a total area 0,275 ha

C_1 - CaO in doses 10 t/ha applied superficially
3 plots of a total area 0,275 ha

C_2 - CaO in doses 10 t/ha superficially and into pits
3 plots of a total area 0,275 ha

D_1 - ground phosphate rock in doses 3 t/ha applied superficially
3 plots of a total area 0,275 ha

D_2 - ground phosphate rock in doses 3 t/ha, superficially and in pits 3 plots of a total area 0,275 ha.

Therefore the experimental area on the slopes comprized 24 plots, of a total area 2,20 ha.
The application of the neutralizers on the slopes required an execution of following operations.

1) Twice done scarifying with cultivator of the entire experimental field comprizing 24 plots of a total area 2,20 ha.
2) Manual digging of pits of 40 x 40 x 40 cm dimensions, and a 1,0 x 1,0 m spacing, for the planting of cuttings, on the 6 plots of an A_2 and B_2 combination of a total area 0,55 ha.
3) Manual digging of pits of dimensions 40 x 40 x 40 cm, and spacing 1,5 x 1,5 m, for the planting of cuttings, on 6 plots of C_2 and D_2 combination, of a total area 0,55 ha.
4) Spreading of ground, burnt agricultural lime on 12 plots of B_1, B_2, C_1, C_2 combination, of a joint area 1,10 ha.
5) Spreading of ground phosphate rock on 6 plots of D_1, D_2 combination, of a total area 0,55 ha.

6) Mixing of neutralizers with soil with a heavy harrow on plots of the B_1, B_2, C_1, C_2, D_1, D_2 combination of a total area 1,65 ha.

7.4.2.2. Mineral fertilization.

On the plots situated on the top portion of the disposal the following mineral NPK fertilization was applied:

x_o - without fertilization (test plots)
30 plots of a total area 0,72 ha

x_1 - PK + N
30 plots of a total area 0,72 ha

x_2 - PK + 2N
30 plots of a joint area 0,72 ha.

The doses and modifications of fertilizers introduced in particular years have been compiled on the table 8.
The employed mineral fertilization is greater than the one provided in a plan of tests, elaborated in 1973. In particular the nitrogenous fertilization in a single dose (N) was increased from 120 kg/ha to 200 kg/ha and in double dose (2 N) from 240 kg to 400 kg/ha. The premise to increase the doses were observations of the growth and health of the plants, and also results of analyses of soils' and plants' chemical composition.
In addition to it on the basis of research carried out in 1974 on the chemical composition of vegetation a plan of supplementary fertilization was prepared, which was realized on the microplots of the previously set up block III, (fig. 4). The following fertilization combinations were applied to them:

x_{11} PK + N + P,
6 microplots of a joint area 0,02 ha

x_{12} PK + N + P, Mg
6 micro-plots of a joint area 0,02 ha.

Mineral fertilization employed on experimental plots of the Lignite Mine Turów.

Table 8

Fertilization component	Doses and forms of mineral fertilizers applied in years		
	1973	1974	1975
N	200 kg/ha of urea i.e. 92 kg/ha of N	100 kg/ha of ammonium nitrate, i.e. 34,5 kg/ha of N	400 kg/ha of ammonium nitrate, i.e. 135 kg/ha of N
2N	400 kg/ha of urea i.e. 184 kg/ha of N	100 kg/ha of ammonium nitrate, i.e. 34,5 kg/ha of N	800 kg/ha of ammonium nitrate, i.e. 270 kg/ha of N
P	300 kg/ha of superphosphate, i.e. 32 kg/ha of P	-	-
K	68 kg/ha of potash salt 60 %, i.e. 32 kg/ha of K	-	-

Moreover on the basis of carried out in 1974 tests on the chemical composition of vegetation a plan of supplementary fertilization was prepared, which was put into effect on the microplots of the earlier on set up block III (fig. 4). The following fertilizer combinations were applied there:

x_{11} PK + N + P_1

6 micro-plots of a joint area 0,02 ha

x_{12} PK + N + P_1 Mg

6 micro-plots of a joint area 0,02 ha.

x_{13} PK + N + P_1MgMo

6 micro-plots of a total area 0,02 ha

x_{21} PK + 2N + P_1

6 micro-plots of a total area 0,02 ha

x_{22} PK + 2N + P_1Mg

6 micro-plots of a total area 0,02 ha

BLOCK III

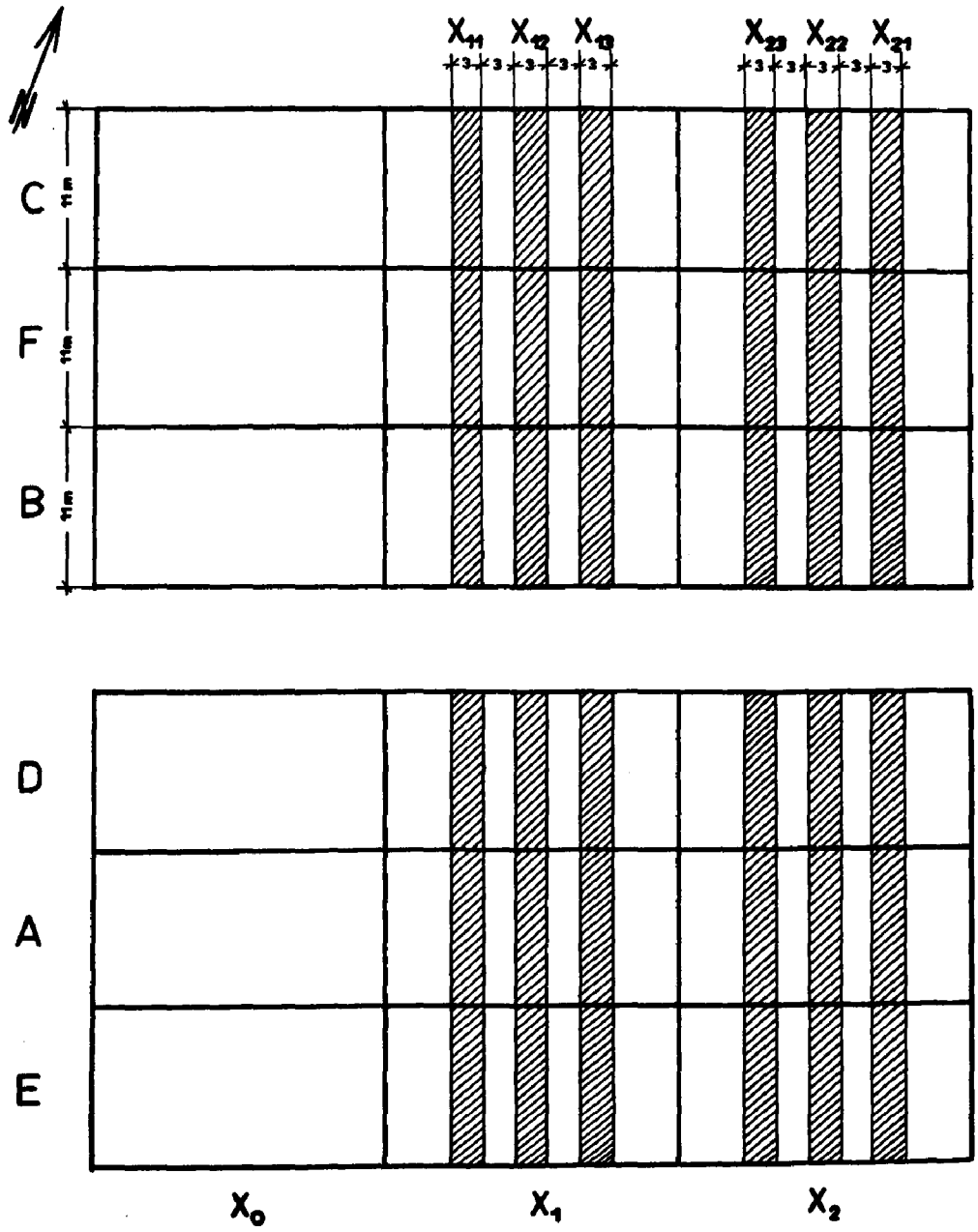


Fig.4 Sketch of microplots arrangements on the block III. The top portion of external spoil disposal of the lignite mine „Turów".

PAGE NOT

AVAILABLE

DIGITALLY

x_{23} PK + 2N + P_1MgMo

6 micro-plots of a total area 0,02 ha.

The experimentation on the block III involved thus 36 micro-plots, of a total area of 0,12 ha.
The doses and forms of fertilization were denoted with symbols PK + N and the PK + 2N correspond to the data contained on table 8, whereas the supplementary fertilization was:

P_1 300 kg/ha of triple superphosphate, granulated 46 % , i.e. 60 kg/ha of P

Mg 101,5 kg/ha of magnesium sulphate, i.e. 10 kg/ha of Mg

Mo 0,37 kg/ha of ammonium molybdate, i.e. 0,20 kg/ha of Mo.

Superphosphate was introduced into the soil before the vegetation started, i.e. on the 21 - 22.IV.1975. The megnesium and molibdenum fertilizers were introduced outside the roots on the 14.V.1975, employing 2 % solution of magnesium sulphate and 0,01 % solution of ammonium molybdate.
Together it was used on the micro-plots:

36 kg of triple superphosphate, granulated 46 %
8 kg of magnesium sulphate,
0,015 kg of ammonium molybdate.

In the period three yearly investigations performed on the disposal of the lignite Turów mine, i.e. in years 1973 - 1975, the treatments connected with fertilization comprized the following operations:

in 1973

1) Harrowing of the whole experimental area, i.e. of 90 plots of a total area 2,16 kg.
2) Sowing out of NPK fertilizers in appropriate doses, on 60 plots of a total area 1,44 ha.
3) Harrowing of the fertilized area, i.e. of 60 plots of a total area 1,44 ha.

in 1974

1) Sowing out of nitrogenous fertilizers outside the roots on 60 plots, i.e. on a total area 1,44 ha.

2) Harrowing of the whole area, i.e. 90 plots of a total area 2,16 ha.

in 1975

1) Sowing outside the roots of a 2/3 annual dose of nitrogen fertilizers on 60 plots, i.e. on a total area of 1,44 ha.

2) Harrowing of the whole surface, i.e. of 90 plots with total area 2,16 ha.

3) Sowing outside the roots of the remaining 1/3 of nitrogenous fertilizer annual dose on 60 plots, of total area 1,44 ha.

4) Manual sowing out of phosphorus fertilizers on the 36 micro-plots of total area 0,12 ha.

5) Distribution of magnesium and molybdenum fertilizers in a form of manual spraying on 24 micro-plots of total area 0,08 ha.

On plots situated on slopes a uniform mineral fertilizing in particular years was applied in following doses and modifications:

1973

N - 70 kg/ha of nitrogen as a clear component i.e. 150 kg/ha of 46 % urea

P - 32 kg/ha of phosphorus as clear component i.e. 300 kg of superphosphate

K - 47 kg/ha of potassium as clear component i.e. 150 kg/ha of 60 % potash salt.

1974

N - 34,5 kg of nitrogen as clear component i.e. 100 kg/ha of 34 % ammonium nitrate.

1975

N - 34,5 kg/ha of nitrogen as clear component i.e. 100 kg/ha of 34 % ammonium nitrate.

The treatments connected with the introduction of mineral fertilizers on the slopes involved the following operations:

in 1973

1) Manual spreading of fertilizers on the whole experimental area comprizing 24 plots of a total area 2,20 ha.

2) Harrowing of the whole experimental area, i.e. of 24 plots of a total area 2,20 ha.

in 1974

1) Manual spreading of nitrogen fertilizers on the whole experimental surface, i.e. on 24 plots of a total area 2,20 ha.

in 1975

1) Manual spreading of nitrogenous fertilizer on the whole experimental surface, i.e. on 24 plots of total area 2,20 ha.

7.4.2.3. Introduction of vegetation.

On the plots situated on the flat top portion of the dispcsal a uniform mixture was introduced of papilionaceous plants together with grasses, of a following composition of species:

Lupinus polyphyllus	25 kg/ha
Lotus corniculatus	8 kg/ha
Trifolium repens	3 kg/ha
Gramineae: Phleum pratense	
Lolium: Perenne, Festuca rubra at 3 kg	9 kg/ha
Together	45 kg/ha

The treatments connected with the introduction of vegetation and its cultivation comprised the following activities:

in 1973

1) Sowing out of mixture of plants on the whole experimental surface, i.e. on 90 plots of total area 2,16 ha.

2) Harrowing of the whole experimental surface, i.e. 90 plots of a total area 2,16 ha.

in 1974

1) Harrowing of the whole experimental surface, i.e. 90 plots of total area 2,16 ha.

2) Twice done mowing of the vegetation on the dates 10 July and 19 September, with mower - grass cutter of a type Orkan, on the experimental surface, i.e. on 90 plots of total area 2,16 ha.

in 1975

1) Harrowing of the whole experimental surface, i.e. on 90 plots of a total area 2,16 ha.

2) Mowing on the 10-th July of vegetation with the mowergrass cutter, type Orkan, on the whole experimental surface, i.e. on 90 plots of a total area 2,16 ha.

On plots set up on the slopes there was introduced in the year 1973 an uniform mixture of papilionaceae with grasses of a following composition of species:

Lupinus polyphyllus	- 30 kg/ha
Lotus corniculatus	- 10 kg/ha
Melilotus albus	- 5 kg/ha
Trifolium repens	- 3 kg/ha
Gramineae: Phleum pratense, Arrhenatherum Elatus, Festuca Rubra at 4 kg	- 12 kg/ha
Together	- 60 kg/ha

Treatments connected with the introduction of mixture seeds on the plots set up on the slopes comprised the following activities:

1) Manual sowing out of seeds on the whole experimental surface, i.e. on the 24 plots of a total area 2,20 ha.

2) Harrowing of the whole experimental surface, i.e. of the 24 plots of a total area 2,20 ha.

The plots localized on the slopes were planted in the spring of 1974 with rooted cuttings and shoot cuttings of trees and bushes, their quantities are specified on the table 9. Connected with it operations involved:

1) Manual digging of pits for planting the cuttings, of dimensions 40 x 40 x 40 cm, and spacing 1,0 x 1,0 m, on the A, and B, combinations, i.e. on 6 plots of a total area 0,55 ha.

2) Manual digging of pits for planting the cuttings, of dimensions 40 x 40 x 40 cm, and spacing 1,5 x 1,5 m, on the C_1, and D_1 combinations, i.e. on 6 plots of total area 0,55 ha.

3) Planting of 13.870 pieces of trees and bushes rooted cuttings and 9.500 specimens of willow shoot cuttings and 9500 poplar shoot cuttings, of the species composition given on table 9.

Notice: On the plots A_2, B_2, C_2, D_2 the pits were dug in the course of operations performance connected with the neutralization execution.

7.4.3. Evaluation of effects of reclamation work carried out on experimental plots set up on external spoil stack, of the Lignite Opencast Mine Turów.

In order to estimate the effects of reclamation work, apart from the current observations made of vegetation and the systematic surveillance of the neutralization progress and a periodical evaluation of the state of soil resourcefulness with nourishing components, there were executed the following operations.

Specification of trees and bushes rooted cuttings and shoot cuttings planted in the spring of 1974, on slope of outer disposal.

Experimental plots of the Lignite Mine Turów - 1974.

Table 9

Species	Block		
	S-I	S-II	S-III
Alnus glutinosa Black alder	pieces 2 500	pieces 2 900	pieces 2 500
Robinia pseudacacia Locust tree	120	140	120
Elaeagnus angustifolia Russian olive	115	130	115
Caragana arborescens Siberian pea shrub.	115	130	115
Larix decidua European larch	350	-	-
Quercus boreàlis, Q. robur Pedunculated oak, red oak	350	240	200
Populus Robusta White Poplar	-	48	-
Populus Hybrida-275, Populus Hybrida-194 Poplar Hybrids-275, 194	100	72	100
Sorbus aucuparia Mountain ash	-	100	-
Rhus typhina Tea plant	300	320	200
Padus serotina Common chokeberry	300	200	300
Fraxinus excelsior European ash	-	320	200
Acer platanoides Common maple	-	160	200
Acer pseudoplatanus Sycamore	-	160	-
Sambucus nigra Golden elder	-	250	100
Carpinus betulus European hornbeam	-	-	100
Fagus silvatica Common beech	-	-	200
together	4 250	5 170	4 450
Willow shoot cuttings - Salix sp.	3 000	3 500	3 000
Poplar shoot cuttings - Populus sp.	3 000	3 500	3 000
together	6 000	7 000	6 000

In the year 1974

1) Determination of the quality of crops - first swath in July, the second in September.

2) Sample taking of vegetation material for the performance of chemical composition analyses - July.

3) Survey of root systems of papilionaceous plants brought in mixtures of many species - last 10 days of September.

4) Visual evaluation of floristic composition of herbaceous plants on particular plots localized on the top flat portion - July.

5) Visual estimation of the herbaceous flora development, and preliminary evaluation of the plantings successfulness on plots localized on the slope - indicatory measurement of annual increments' values - September/October.

In 1975

1) Determination of the quantity of crops - first crop in July.

2) Sample taking of vegetation material for the chemical composition analyses - July.

3) Measurement of the root systems of papilionaceous plants introduced into mixes with many species.

4) Visual evaluation of the vegetation composition of herbaceous flora on particular plots - July.

5) Measurements of the height and thickness of cuttings planted on the slopes, prior to the commencement of growing - April.

6) Measurements of annual increment in height of the cuttings - October/November.

7.4.3.1. Vegetation.

On the plots established on flat top portion of the disposal a qualitative and quantitative evaluation of the portion of biomass above the ground of crops from the first, swath of papilionaceous plants and grasses mixture was made, and also was determined the weight of the root mass. The dry weather prevailing during the summer of 1975 hindered the regrowth of green growth to such extent that no second swath of hay could be obtained.

The first crop in 1975 had a very good growth of vegetation, and also the denseness of green growth, the regrowth of which and also floristic composition, was strictly connected with the employed combination of neutralization and with the quantity of the mineral NPK fertilization (tab. 10). The largest proportion of papilionaceous plants was ascertained on a control plot without fertilization (X_o), on the D combination. On plots neutralized and fertilized the vegetation composition of the green growth was more favourable in 1975 than was in 1974, as the proportion of papilionaceous plants in the growth was greater. The increased doses of nitrogenous fertilization in majority of cases diminished the proportion of this group of plants to the advantage of grasses.

From the introduced plants the most sucessful ones have shown themselves to be from Gramineae: the Phleum pratense and from Papilionaceae the: Lupinus polyphyllus. With this it was observed a pronounced improvement in the development of Lotus corniculatus. On the fields neutralized with the ground agricultural quicklime, CaO, the proportion in green growth of Lotus corniculatus increased by 10-20 % in relation to the 1974 year. On experimental plots the crops acquired in 1975 were high (table 11, 12). In the years 1974 and 1975 maximum crops were obtained by various combinations of the way of neutralization for particular levels of fertilization:

x_o - maximum crop in years 1974 and 1975 on the F combination

x_1 - maximum crop in the year 1974 on F combination, and in 1975 on the D combination

x_2 - maximum crop in 1974 on F combination, and in the year 1975 on the D combination.

Participation of grasses and papilionaceous plants in the green growth dependent on the kind of neutralization and fertilization NPK - 2-nd year of vegetation.

Experimental plot of "Turów" mine - 1974 and 1975

Table 10

Kind of fertilization	Combination of the kind of neutralization / Plant / Year	A		B		C		D		E		F	
		% share in green growth											
		1974	1975	1974	1975	1974	1975	1974	1975	1974	1975	1975	1975
X_0	Gramineae x/	96	99	95	88	93	88	38	10	94	98	92	90
	Lupinus polyphyllus	3	-	4	10	6	10	12	30	3	+	7	9
	Trifolium repens	+	+	+	+	+	+	48	40	2	+	+	+
	Lotus corniculatus	+	+	+	+	+	+	2	20	+	+	+	+
X_1	Gramineae x/	98	99	87	88	83	60	66	50	98	98	96	90
	Lupinus polyphyllus	+	-	2	10	6	10	6	10	1	+	3	9
	Trifolium repens	+	+	10	+	10	10	27	20	+	+	+	+
	Lotus corniculatus	+	+	+	+	+	20	+	20	+	+	+	+
X_2	Gramineae x/	96	99	92	70	92	79	79	60	98	99	95	98
	Lupinus polyphyllus	+	-	4	10	3	10	6	10	+	+	4	+
	Trifolium repens	3	+	2	10	4	+	14	10	+	-	+	+
	Lotus corniculatus	+	+	2	10	+	10	+	20	+	-	+	+

x/ Amongst Gramineae prevail Phleum pratense

\+ occurs occasionally

\- species not occurring

The sizes of crops and mechanical composition of papilionaceous plants mixture with grasses, dependent on the method of neutralization, and the kind of NPK fertilization.

Experimental plots of the Opencast Mine "Turów" - 1974

Table 11

Combinations of the neutralization method	Kind of fertilization	Crops q/ha				Content in the dry mass of plants mixture x/													
		Crop of fresh mass		Total of crops I and II swath		microcontents %									microcontents ppm				
		I swath 10.VII. 1974 x/	II swath 19.IX. 1974 x/	fresh mass	air-dried mass	Na	K	Ca	Mg	P	N	S	C	C/N	Zn	Cu	Mn	Fe	Al
A	X_0	2,9	7,2	10,1	7,6	0,03	2,33	0,54	0,09	0,15	3,35	0,28	41,02	12,2	337	10	165	668	390
	X_1	38,0	13,5	51,5	13,9	0,05	2,50	0,68	0,10	0,17	1,97	0,36	38,60	19,5	261	8	175	793	231
	X_2	64,2	36,2	100,4	28,1	0,06	2,34	0,54	0,11	0,14	2,21	0,27	38,60	17,5	376	10	192	829	280
B	X_0	5,6	3,5	9,1	2,3	0,03	1,72	0,55	0,09	0,12	2,57	0,18	40,70	15,8	203	8	154	833	173
	X_1	56,3	17,3	73,6	24,3	0,04	2,36	0,51	0,11	0,16	1,75	0,24	38,60	22,0	306	10	235	663	160
	X_2	50,6	30,5	81,0	17,8	0,05	2,99	0,54	0,13	0,18	2,21	0,30	38,60	17,5	398	10	185	799	163
C	X_0	6,6	7,3	13,9	7,2	0,03	2,14	0,54	0,11	0,17	1,75	0,25	38,60	22,0	268	6	208	736	281
	X_1	60,4	15,9	76,3	22,9	0,04	2,37	0,54	0,12	0,16	1,52	0,21	38,60	23,4	260	6	286	663	251
	X_2	76,2	32,5	108,7	32,6	0,05	2,65	0,55	0,12	0,13	1,92	0,30	39,02	20,3	348	9	237	623	176
D	X_0	35,2	18,2	53,4	13,9	0,03	2,67	0,34	0,12	0,20	1,52	0,22	38,60	25,4	246	5	206	280	110
	X_1	54,8	22,1	77,0	19,2	0,05	2,81	0,50	0,12	0,19	1,35	0,24	39,40	29,1	273	6	262	882	333
	X_2	79,0	33,4	112,4	27,0	0,07	2,53	0,48	0,12	0,24	1,61	0,36	39,02	24,2	341	10	197	871	231
E	X_0	20,1	5,2	25,8	8,5	0,04	2,04	0,34	0,10	0,21	1,61	0,19	39,02	24,2	317	6	164	346	91
	X_1	48,8	23,7	72,5	21,8	0,07	2,22	0,49	0,12	0,22	1,48	0,25	39,45	26,7	613	7	165	817	340
	X_2	50,6	27,9	78,4	25,1	0,08	2,45	0,52	0,13	0,26	2,10	0,37	41,93	20,0	454	11	178	1167	479
F	X_0	44,6	27,4	72,0	21,6	0,10	2,23	0,48	0,18	0,24	2,23	0,48	42,20	18,0	543	11	203	854	426
	X_1	60,8	45,1	105,9	30,7	0,07	2,35	0,55	0,18	0,28	4,05	0,47	39,45	9,8	480	19	229	957	274
	X_2	57,2	59,9	117,1	35,1	0,10	2,65	0,49	0,15	0,26	2,49	0,47	40,70	16,4	485	14	252	1128	389

x/ Average content from 5 repetitions

x/ Species composition of the mixture specified on table.

Size of crops and chemical composition of papilionaceous plants mixture with grasses in the 2-nd year of vegetation, dependent on the method of neutralization and the kind of NPK fertilization.

Experimental plots of the "Turów" Lignite Surface Mine - 1975

Table 12

Combinations of the method of neutralization	Kind of fertilization	Crops q/ha		Content in the dry mass of plant mixture *)											
		I swath x) 7.VIII.1975		macrocontents %							microcontents ppm				
		fresh mass	air-dry mass	Na	K	Ca	Mg	P	N	S	Zn	Cu	Mn	Fe	Mo
A	X_0	8,8	4,8	traces	2,1	0,2	0,09	0,23	0,4	0,2	41	5	207	196	1,65
	X_1	66,3	31,7	0,02	1,5	0,2	0,09	0,19	1,0	0,2	59	3	164	272	1,82
	X_2	91,8	41,0	traces	1,7	0,2	0,10	0,19	1,4	0,2	76	6	164	256	1,16
B	X_0	8,1	4,2	traces	1,3	0,2	0,08	0,19	1,0	0,2	33	4	273	371	3,00
	X_1	105,0	42,0	0,02	1,9	0,3	0,14	0,29	1,3	0,3	73	4	201	242	1,78
	X_2	92,4	47,1	0,04	2,1	0,3	0,15	0,25	1,9	0,3	98	3	207	262	2,48
C	X_0	14,0	8,8	traces	1,1	0,3	0,11	0,23	0,6	0,3	44	8	274	665	1,35
	X_1	96,7	40,0	traces	2,0	0,3	0,13	0,31	1,3	0,2	65	5	164	272	1,54
	X_2	111,2	42,9	0,03	2,1	0,3	0,13	0,48	1,7	0,3	68	4	120	142	2,24
D	X_0	85,3	24,8	0,03	2,0	0,8	0,24	0,47	1,8	0,2	101	8	352	433	1,92
	X_1	108,1	59,5	0,02	1,9	0,2	0,12	0,40	1,2	0,2	49	3	233	218	1,37
	X_2	152,8	78,6	traces	2,2	0,2	0,13	0,40	1,4	0,3	76	6	218	240	1,46
E	X_0	18,1	10,1	traces	0,1	0,1	0,05	0,31	0,5	0,2	40	4	76	207	0,85
	X_1	90,6	38,2	0,02	2,0	0,1	0,11	0,38	0,7	0,2	69	4	247	338	0,71
	X_2	94,1	41,7	0,03	2,2	0,2	0,13	0,39	1,4	0,2	68	3	161	330	0,62
F	X_0	61,3	37,2	0,07	1,6	0,2	0,09	0,38	0,7	0,2	61	4	149	267	0,40
	X_1	101,8	42,9	0,03	1,7	0,2	0,14	0,44	1,5	0,3	91	4	198	303	1,87
	X_2	106,2	54,6	0,05	2,1	0,2	0,14	0,38	2,1	0,4	99	8	224	480	0,70

x) - Average value of four repetitions

*) - Species composition of the mixture specified on table.

Notice: Owing to unfavourable meteorological conditions only 1 swath was gathered.

With the application of supplementary fertilization with phosphorus, magnesium and molybdenum on the microplots the maximum results gave D combination (table 13). Parallel with increased yields of the portion above ground of plants, an increased bulk of root systems was occurring, especially so with the Papilionaceae. The main mass of the Gramineae roots was concentrated in the layer 0-10 cm, and of the papilionaceous plants in the layer 0-30 cm. The tap roots of Lupinus were reaching in places even the 100 cm depth, and their mass was clearly greater than in previous year. A particularly profuse occurrense of Rhizobium nodules on the roots of Lupinus was ascertained.

A low content of Ca, Mg N and high content of P, Zn, Mn, Fe and Mo (table 12) characterises the analysed vegetable material. In comparison with the year 1974 the plants contained less K, Ca, N, S, Fe, Zn, and more of P. This impoverishment of hay in some nutrients, can be explained primarily by the so called dilution effect, as the crops acquired in 1975 are much poorer than those acquired in the 1974 year. The assimilation of the mentioned components including also the phosphorus was increasing proportionally with the size of acquired crops (table 14,15) of the employed methods of neutralization; the best effect on the chemical composition of plants in the second year of vegetation gave the D combination.

The nitrogenous fertilization in a form of saltpetre (NO_3) improved the assimilation of majority of components, chiefly of K, Ca, Mg, P, N, S, Zn and Fe. Additional phosphorus and magnesium fertilization brought onto the micro-plots has increased not only the content of phosphorus and magnesium in the plants but also the nitrogen and the sulphur (table 13). The assimilation of nutritious components on the micro-plots was materially higher than on plots without an additional phophorus and magnesium fertilization applied on them (table 16).

The located on the slopes plots were in the year 1973 sown over with a mixture of grasses with papilionaceous plants, and in the spring of 1974 were planted over with the root and shoot cuttings of various kinds of trees and bushes. The object of assessment was then both the herbaceous and the tree and bush vegetation, in various aspects of its suitability for the biological lining and for the silvicultural adaptation of the slopes.

The size of crops and chemical composition of papilionaceous plants mixture with grasses, dependent on the method of neutralization, the level and kind of fertilization.
Microplots on III block, Surface Mine of Lignite "Turów" - 1975.

Table 13

Combination of the method of neutralization	Kind of fertilization	Crops q/ha		Content in dry mass of plant mixture										
		I swath 7.VII.1975		macrocomponents %							microcomponents ppm			
		fresh mass	air-dried mass	Na	K	Ca	Mg	P	N	S	Zn	Cu	Mn	Fe
A	P_1	133,8	64,1	0,02	2,0	0,2	0,11	0,40	0,9	0,17	38	4	297	385
	X_1P_1Mg	158,3	75,8	0,02	2,1	0,2	0,15	0,46	1,4	0,19	69	6	360	3124
	P_1MgMo	86,5	41,4	0,02	1,7	0,2	0,12	0,36	0,8	0,14	44	3	311	371
	P_1	116,0	51,9	0,03	2,2	0,3	0,19	0,26	1,6	0,24	63	9	333	577
	X_2P_1Mg	104,2	46,6	0,06	2,0	0,1	0,16	0,26	1,3	0,28	78	7	283	555
	P_1MgMo	150,7	67,3	0,05	2,4	0,2	0,17	0,58	1,5	0,40	80	8	292	349
B	P_1	129,2	51,7	0,02	1,9	0,2	0,14	0,40	1,0	0,17	50	7	387	469
	X_1P_1Mg	138,8	55,5	0,03	2,1	0,2	0,15	0,47	1,2	0,21	48	5	436	338
	P_1MgMo	60,1	24,0	0,02	1,4	0,2	0,12	0,38	0,8	0,17	49	2	398	272
	P_1	144,2	74,6	0,02	2,5	0,4	0,22	0,60	1,5	0,31	63	8	264	440
	X_2P_1Mg	129,2	66,0	0,02	2,2	0,3	0,15	0,58	1,5	0,28	67	7	284	341
	P_1MgMo	160,2	81,7	0,04	1,7	0,4	0,20	0,48	1,4	0,31	80	3	297	275
C	P_1	91,0	37,7	0,03	1,7	0,6	0,19	0,46	1,4	0,31	66	3	310	352
	X_1P_1Mg	94,6	39,2	0,03	2,2	0,3	0,18	0,49	1,0	0,24	48	7	450	300
	P_1MgMo	113,8	47,1	0,01	2,0	0,4	0,17	0,39	1,4	0,17	34	8	377	311
	P_1	100,1	38,6	0,01	2,0	0,4	0,14	0,53	1,3	0,21	50	7	212	305
	X_2P_1Mg	111,5	43,0	0,02	2,0	0,3	0,17	0,58	1,5	0,28	63	7	324	451
	P_1MgMo	73,7	28,5	0,10	2,0	0,3	0,15	0,48	1,4	0,27	61	3	110	181
D	P_1	160,2	88,1	0,01	2,1	0,4	0,19	0,41	1,3	0,22	66	6	310	440
	X_1P_1Mg	186,6	102,6	0,01	2,4	0,3	0,18	0,55	1,3	0,24	55	7	297	374
	P_1MgMo	147,9	81,3	0,04	1,9	0,4	0,20	0,44	1,2	0,17	66	4	368	374
	P_1	156,1	80,2	0,06	2,5	0,6	0,23	0,58	2,2	0,24	55	4	168	264
	X_2P_1Mg	145,6	74,8	0,08	2,0	0,2	0,15	0,38	1,3	0,31	73	4	353	308
	P_1MgMo	162,0	93,6	0,04	2,5	0,2	0,19	0,60	1,5	0,37	72	6	402	440
E	P_1	119,2	50,2	0,01	1,9	0,2	0,11	0,35	0,9	0,17	35	2	286	275
	X_1P_1Mg	158,3	66,7	0,01	2,2	0,2	0,11	0,46	0,9	0,29	46	5	246	275
	P_1MgMo	63,7	26,8	0,01	1,9	0,2	0,13	0,34	0,7	0,17	51	4	490	2376
	P_1	106,1	48,0	0,06	2,6	0,4	0,23	0,51	1,8	0,29	58	8	286	517
	X_2P_1Mg	117,4	52,0	0,06	2,6	0,2	0,20	0,51	1,7	0,42	88	9	297	748
	P_1MgMo	156,1	69,1	0,02	2,2	0,2	0,14	0,44	0,8	0,28	52	7	269	286
F	P_1	147,0	61,9	0,02	2,1	0,2	0,15	0,58	1,3	0,24	133	9	374	4 972
	X_1P_1Mg	108,3	45,6	0,02	1,7	0,3	0,17	0,48	1,1	0,21	53	4	371	352
	P_1MgMo	132,9	55,9	0,03	2,2	0,4	0,24	0,67	1,9	0,28	53	8	316	358
	P_1	137,9	70,9	0,02	3,1	0,4	0,23	0,91	2,5	0,21	57	9	275	440
	X_2P_1Mg	150,2	77,2	0,02	2,6	0,3	0,21	0,62	2,0	0,24	51	8	206	242
	P_1MgMo	153,3	78,8	0,07	1,9	0,2	0,21	0,54	1,9	0,24	73	6	266	374

Explanation:

P_1 60 kg/ha (treble superphosphate, 46 % granulated)
Mg 10 kg/ha (magnesium sulphate), delivered outside the roots
Mo 0,2 kg/ha, (ammonium molybdate) delivery outside the roots

The quantity of components assimilated by the plants' portions above the ground, dependent on the method of neutralization and NPK - fertilization - 1-st year of vegetation.

Experimental plots of the lignite surface mine "Turów" - 1974.

Table 14

Combinations of the neutralization method	Kind of fertilization	Yields q/ha		Quantity of assimilated with the yields of I hay swath, in kg/ha									
		I Swath, 7.VIII.1975		macro - elements							micro - elements		
		fresh mass	air-dried mass	Na	K	Ca	Mg	P	N general	S total	Zn	Mn	Fe
A	X_0	2,9	1,6	0,1	3,4	0,9	0,1	0,2	4,9	0,4	0,1	0,1	0,1
	X_1	38,0	10,5	0,5	24,2	6,6	1,0	1,7	19,1	3,5	0,3	0,2	0,8
	X_2	64,2	20,0	1,2	43,0	10,0	2,0	2,6	40,6	5,0	0,7	0,4	1,5
B	X_0	5,6	1,8	0,1	2,8	0,8	0,1	0,2	4,0	0,3	0,1	0,1	0,1
	X_1	56,3	17,5	0,7	38,0	8,2	1,8	2,6	28,2	3,9	0,5	0,4	1,1
	X_2	50,6	12,5	0,6	34,4	6,2	1,5	2,1	25,4	3,5	0,5	0,2	0,9
C	X_0	6,6	4,0	0,1	7,9	2,0	0,4	0,6	6,4	0,9	1,0	0,1	0,3
	X_1	60,4	18,5	0,7	40,3	9,3	2,0	2,8	25,9	3,5	0,4	0,5	1,1
	X_2	76,2	26,0	1,3	62,7	13,0	2,9	3,1	45,5	7,0	0,8	0,6	1,5
D	X_0	35,2	10,0	0,3	20,9	3,1	1,0	1,9	14,0	2,0	0,2	0,2	0,3
	X_1	54,8	15,2	0,8	39,7	7,1	1,7	2,7	19,1	3,3	0,4	0,4	1,3
	X_2	79,0	20,0	1,2	46,0	8,8	2,2	4,6	29,4	6,6	0,6	0,4	1,6
E	X_0	20,1	7,0	0,3	13,0	2,2	0,6	1,4	10,3	1,2	0,2	0,1	0,2
	X_1	48,8	16,8	1,0	33,6	7,4	1,8	3,4	22,3	3,9	0,9	0,3	1,2
	X_2	50,6	19,5	1,4	43,1	9,2	2,3	4,7	36,9	6,4	0,8	0,3	2,1
F	X_0	44,6	15,5	1,4	31,5	6,8	2,5	3,4	31,5	6,8	0,8	0,3	1,2
	X_1	60,8	19,5	1,2	41,3	9,5	3,1	5,1	71,0	8,2	0,8	0,4	1,7
	X_2	57,2	21,8	2,0	52,1	9,6	3,1	5,2	48,8	9,2	1,0	0,5	2,5

The amounts of components assimilated by plant above the ground portions, dependent on the method of neutralization and on NPK fertilization - 2-nd year of vegetation.

Experimental plots of the lignite surface mine "Turów" - 1975

Table 15

Combinations of the neutralization method	Type of fertilization	Yields in q/ha		Amounts of assimilated with the yields of the I swath of hay, in kg/ha										
		I swath 7.VII.1975		macro - components							micro - components			
		fresh mass	air-dry mass	Na	K	Ca	Mg	P	N	S	Zn	Cu	Mn	Fe
A	X_0	8,8	4,8	traces	10,0	1,0	0,4	1,1	1,9	1,0	0,02	0,002	0,10	0,09
	A_1	66,3	31,7	0,6	47,0	6,0	2,9	6,1	32,0	6,3	0,20	0,010	0,52	0,86
	X_2	91,8	41,0	traces	70,0	8,0	4,1	7,8	57,4	8,2	0,30	0,025	0,67	1,05
B	X_0	8,1	4,2	traces	5,0	0,8	0,3	0,8	4,2	0,8	0,01	0,002	0,11	0,16
	X_1	105,0	42,0	0,8	80,0	13,0	5,9	12,2	54,6	12,6	0,30	0,017	0,84	1,02
	X_2	92,4	47,1	1,9	99,0	14,0	7,1	11,8	89,5	14,1	0,46	0,014	0,98	1,23
C	X_0	14,8	8,8	traces	10,0	3,0	10,0	2,0	5,3	2,6	0,04	0,007	0,24	0,58
	X_1	96,7	40,0	traces	80,0	12,0	5,2	12,4	52,0	8,0	0,26	0,020	0,66	1,09
	X_2	111,2	42,9	1,3	90,0	13,0	5,6	14,6	73,0	12,9	0,29	0,017	0,52	0,61
D	X_0	85,3	24,8	0,7	50,0	20,0	6,0	11,7	45,0	5,0	0,25	0,020	0,87	1,07
	X_1	108,1	59,5	1,2	114,0	12,0	7,2	24,0	71,4	12,0	0,29	0,018	1,39	1,30
	X_2	152,8	78,6	traces	174,0	16,0	10,3	31,6	110,6	23,6	0,60	0,047	1,72	1,89
E	X_0	18,1	10,1	traces	1,0	1,0	0,5	3,1	5,0	2,0	0,04	0,040	0,08	0,21
	X_1	90,6	38,2	0,8	76,0	4,0	4,2	14,4	26,7	7,6	0,26	0,015	0,94	1,29
	X_2	94,1	41,7	1,2	92,0	8,0	5,5	16,4	58,4	8,3	0,28	0,013	0,67	1,38
F	X_0	61,3	37,2	2,6	59,0.	7,0	3,3.	14,1	26,0	7,4	0,23	0,015	0,55	1,00
	X_1	101,8	42,9	1,3	73,0	9,0	6,0	18,9	64,4	13,0	0,39	0,017	0,85	1,30
	X_2	106,2	54,6	2,7	116,0	11,0	7,7	20,9	114,7	21,8	0,54	0,044	1,22	2,62

The amount of components assimilated by the plant portions above the ground, dependent on the method of neutralization and the NPK fertilization - 2-nd year of vegetation. Micro-plots on the III block, lignite surface mine Turów- 1975.

Table 16

Combinations of the neutralization method	Kind of fertilization	Yields in q/ha I swath 7.VII.75		Amount of assimilated with the yields of the I swath of hay, in kg/ha										
				macro - elements							micro - elements			
		fresh mass	air-dry mass	Na	K	Ca	Mg	P	N	S	Zn	Cu	Mn	Fe
A	P_1	133,8	64,1	1,28	128,2	12,8	7,0	25,6	57,7	10,9	0,24	0,03	1,90	2,47
	X_1P_1Mg	158,3	75,8	1,52	159,2	15,2	11,4	34,9	106,1	14,4	0,52	0,05	1,73	2,37
	P_1MgMo	86,5	41,4	0,83	70,4	8,3	5,0	15,0	33,1	5,8	0,18	0,01	1,29	1,54
	P_1	116,0	51,9	1,56	114,2	15,6	9,9	13,5	83,0	12,5	0,33	0,05	1,73	3,00
	X_2P_1Mg	104,2	46,6	2,80	93,2	4,7	7,5	12,1	60,6	13,0	0,36	0,03	1,32	2,59
	P_1MgMo	150,7	67,3	3,36	161,5	13,5	11,4	39,0	101,0	27,0	0,54	0,05	1,97	2,35
B	P_1	129,2	51,7	1,03	98,2	10,3	7,2	20,7	51,7	8,8	0,26	0,04	2,00	2,42
	X_1P_1Mg	138,8	55,5	1,66	116,6	11,1	8,3	26,1	66,6	11,7	0,27	0,03	2,42	1,88
	P_1MgMo	60,1	24,0	0,48	33,6	4,8	2,9	9,1	19,2	4,1	0,12	0,01	9,55	0,65
	P_1	144,2	74,6	1,50	186,5	29,8	16,4	44,8	111,9	23,1	0,47	0,06	1,97	3,28
	X_2P_1Mg	129,2	66,0	1,32	145,2	19,8	9,9	38,3	99,0	18,5	0,44	0,05	1,87	2,25
	P_1MgMo	160,2	81,7	3,27	138,9	32,7	16,3	39,2	114,4	25,3	0,65	0,02	2,43	2, 25
C	P_1	91,0	37,7	1,13	64,1	22,6	7,2	17,3	52,8	11,7	0,25	0,01	1,17	1,33
	X_1P_1Mg	94,6	39,2	1,18	86,2	11,8	7,1	19,2	39,2	9,4	0,19	0,03	1,76	1,18
	P_1MgMo	113,8	47,1	0,47	94,2	18,8	8,0	18,4	65,9	8,0	0,16	0,04	1,78	1,47
	P_1	100,1	38,6	0,39	77,2	15,4	5,4	20,4	50,2	8,1	0,19	0,03	0,82	1,18
	X_2P_1Mg	111,5	43,0	0,86	86,0	12,9	7,3	24,9	64,5	12,0	0,27	0,03	1,39	1,94
	P_1MgMo	73,7	28,5	2,85	57,0	8,6	4,3	13,7	39,9	7,7	0,17	0,01	0,31	5,16
D	P_1	160,2	88,1	0,88	185,0	35,2	16,7	36,1	114,5	19,4	0,58	0,05	2,73	3,88
	X_1P_1Mg	186,6	102,6	1,03	246,2	30,8	18,5	56,4	133,4	24,6	0,56	0,07	3,05	3,84
	P_1MgMo	147,9	81,3	3,25	154,5	32,5	16,3	35,8	97,6	13,8	0,54	0,03	2,99	3,04
	P_1	136,1	80,2	4,81	200,5	48,1	18,4	46,5	176,4	19,2	0,44	0,03	1,35	2,12
	X_2P_1Mg	145,6	74,8	5,98	149,6	15,0	11,4	28,4	97,2	23,2	0,55	0,03	2,64	2,30
	P_1MgMo	162,0	93,6	3,74	234,0	18,7	17,8	56,2	140,4	34,6	0,67	0,06	3,76	4,12
E	P_1	119,2	50,2	0,50	95,4	10,0	5,5	17,6	45,2	8,5	0,18	0,01	1,44	1,38
	X_1P_1Mg	158,3	66,7	0,67	146,7	13,3	7,3	30,7	60,0	19,3	0,31	0,03	1,64	1,83
	P_1MgMo	63,7	26,8	0,27	50,9	5,4	3,5	9,1	18,8	4,6	0,14	0,01	1,31	6,37
	P_1	106,1	48,0	2,88	124,8	19,2	11,0	24,5	86,4	13,9	0,28	0,04	1,38	2,48
	X_2MgMo	117,4	52,0	3,12	135,2	10,4	10,4	26,5	88,4	21,8	0,46	0,05	1,54	3,89
	P_1MgMo	156,1	69,1	1,38	152,0	13,8	9,7	30,4	55,3	19,3	0,36	0,05	1,86	1,98
F	P_1	147,0	61,9	1,25	129,9	12,5	9,3	35,9	80,5	14,9	0,82	0,06	2,44	3,08
	X_1P_1Mg	108,3	45,6	0,91	77,5	13,7	7,8	21,9	50,2	9,6	0,24	0,02	1,69	1,61
	P_1MgMo	132,9	55,9	1,68	122,9	22,4	13,4	37,5	106,2	15,6	0,30	0,04	1,77	2,00
	P_1	137,9	70,9	1,42	219,8	28,4	16,3	64,5	177,2	14,9	0,40	0,06	1,95	3,12
	X_2P_1Mg	150,2	77,2	1,54	200,7	23,2	16,2	47,9	154,4	18,5	0,39	0,06	1,59	1,87
	P_1MgMo	153,3	78,8	5,52	149,7	15,8	16,5	42,6	149,7	18,9	0,58	0,05	2,10	2,95

Explanations: P_1 60 kg/ha of treble superphosphate, granulated 46 %
Mg 10 kg/ha (magnesium sulphate), supply outside roots
Mo 0,2 kg (ammonium molibdate), supply outside roots

In the year 1975 the coverage of the slopes surface with the herbaceous vegetation amounted to 70 - 80 %. The best development occurred on the block S-III, i.e. on the northern exposure. Among the introduced species of vegetation the greatest dynamics of growth and expansion - was showing the Phleum pratense. Thanks to its qualities it sown created compact green fields well protecting the surface against an erosion. The differences in its development on the slopes of various exposures were comparatively small, from which one can deduce, that this plant can well sustain the prolonged periods of drought. The Phleum pratense has shown also a weak reaction to a strong acidification of the soil medium. All this qualifies it as a plant very suitable for the stopping of erosion on the slopes. It presents however a very strong competition to the cuttings growth and especially to the shoot cuttings of trees and bushes, therefore one can introduce this plant onto the fragments of slopes, which shall not be planted over by the tree vegetation, and its participation in the mixture of herbaceous vegetation accompanying the tree planting, should be minimal.

Arrhenatherum elatius and Festuca rubra, which were selected in the composition of mixture sown on the slopes did not create a compact green growth, they performed the anti-erosion function much more poorly, but did constitute a lesser competition to the being introduced shoot cuttings.

In the first 2 years the papilionaceous plants which were entering the composition of the mixture protected the area of the slopes against the erosion not so well as the grasses, as they were growing still very thinly. Their soil creating, phytomeliorating or nursing effects did not manifest themselves yet, although one could expect this, especially from the Lupinus, already in the following year of growing.

The year 1975 constituted only the second vegetation season for the root and shoot cuttings of trees and bushes planted on the slopes. Therefore it is to short time to draw on the basis of observations and biometric measurements the final conclusions regarding the suitability of particular species for the biological consolidation. The adaptation of the cuttings still continues to the new and difficult

habitat conditions, the consequence of which is their general weakening, the drop-outs and very small increases in height. One of the main causes of a long lasting acclimatization of cuttings on the slopes are the humidity conditions. The unfavourable distribution of precipitation conditions in the years 1974 and 1975 worsened these additionally. This made it more difficult to evaluate the suitability of various species planned for the biological consolidation of the slopes and also the differences among the employed combinations of neutralization were being made less distinguishable (table 17).

From the anti - erosion species, suitable for the biological consolidation of slopes is the Caragana arborescens, whose root taking can be estimated as 65 - 75 %, and the increments at about 20 cm (2 - 26 cm). The remaining species from the anti-erosion group, i.e. the Elaeagnus angustifolia and Robinia pseudocacia were taking roots less strongly.

The majority of the Elaeagnus angustifolia specimens suffered illness, and the Robinia psudacacia was being harmed by wild animals.

Amongst the phytomeliorating species one can rate highly the Alnus glutionosa, which was taking root very well, as it was successful 95 %, and the yearly increments were about 40 cm (24 - 69 cm).

Among the biocenosis species a good development and only few fall-outs had the Padus serotica. The ability to take roots of the other introduced species oould be rated as about 80 - 90 %. To the well acclimatizing ones from the species of final destination belong among others the Fraxinus and the Acer pseudoplatanus.

About 30 % of the area of plots was planted with the shoot cuttings of willow and of poplar. The short period of the experiments duration does not warrant, as already mentioned, the evaluation of this method of a biological consolidation of slopes. The ability of root taking of the planted shoot cutting in the 2-nd year of vegetation was rated as the 50 - 60 %, the annual increments of willow cuttings amounted on average to 30 cm, and of poplar cuttings about 20 cm. High proportion of the fall-outs can be explained with the stifling by the grasses, and with the frequent damages made by wild animals.

A full evaluation of methods of the slopes' biological consolidation with tree and bush vegetation can only be formulated after some further observations' accomplishment.

Orientational amounts of fall-outs and increments of cuttings of several species of trees introduced onto the slopes within the framework of biological consolidation.
Experimental plots of the lignite surface mine "Turów" - 2-nd year of vegetation - 1975.

Table 17

Denotation of the experimental area	Combination of the neutralization method	Alnus glutinosa		Caragana arborescens		Padus serotina		Rhus typhyina	
		Fall-out, %	Increase in height, cm	Fall-out, %	Increase in height, cm	Fall-out, %	Increase in height, cm	Fall-out, %	Increase in height, cm
S-I, south	A	x	46	40	16	x	15	x	15
	B	x	39	40	21	x	9	x	18
	C	x	60	25	2	x	21	x	16
	D	x	41	15	26	x	5	x	20
S-II, west	A	x	24	40	7	-	-	x	14
	B	x	32	x	2	x	28	x	11
	C	x	40	30	13	x	12	x	19
	D	x	43	40	18	-	-	x	19
S-III, north	A	x	38	35	11	x	14	x	30
	B	x	44	15	16	-	-	x	23
	C	x	47	25	19	-	-	x	-
	D	x	48	x	8	-	-	x	-

x - sporadical fall-out of cuttings

\- - the species not assessed.

7.4.3.2. Soils.

In order to evaluate the effects of neutralization and the fertilizer requirements, in the year 1975 samples of soils were taken from the experimental plots. The averaged results of the pedological chemical analyses were shown on the table 18 and on fig. 6. They permit to formulate the presented below generalizations and conclusions.

1) The most pronounced effects of neutralization, expressing themselves with a raised soil reaction (pH), a depressed hydrolytic acidity (H_h) and the content of replaceable aluminium (Al_r), occurred on plots, on which was applied 10 t/ha of CaO, introduced in two layers, (C combination), and one such on which 2 neutralizers were used simultaneously, namely the 5 t/ha of CaO together with the 3 t/ha of ground phosphate rock (D combination).

2) In the case of B, E, F combination, the changes in the value of pH, H_h and Al_r stay as a rule within the sector of variability encountered on the not having been neutralized soils of this spoil stack.

3) In the year 1975, i.e. 2 years after the applied neutralization and after vegetation introduction, the differences between the chemical properties of soils in the layers 0-10 and 10-20 cm have decreased. In the layers deeper placed no changes were ascertained in properties such as could be linked with the neutralizers' use.

4) The assessment of the habitat conditions improvement effected in the course of the toxicity neutralization of acid soils on the spoil stacks prepared on the basis of comparisons made regarding the pH, H_h and Al_r can be misleading. The crops gathered from the experimental plots, on which the pH, H_h and Al_r indicators were similar - are pointing at it. The highest crop of hay gathered from the D combination was almost 2-times greater than on the control plots (A combination the value of this crop was almost the same as on control plots, which were altogether without neutralization.)

Simultaneously on the plots of the F combination, marked with very low reaction, and also with high hydrolytic acidity and the content of replaceable aluminium, a distinct rise in the crops of hay occurred in comparison with the control plot - and to that at all levels of mineral fertilization.

5) Analysis of the crops sizes, carried out for various combinations of the neutralization method and by various levels of fertilization employed on the experimental plots of the top portion of the lignite surface mine "Turów" spoil stack brought the conclusion that the effects of fertilization can also in some cases be higher than the effects acquired through a neutralization carried out by means of only one component. This is of course valid only for soils weakly toxic. A clear change in the quality of medium connected with the application of a combined two-componential neutralization of such soils, almost in all cases intensified the effect of fertilization.

6) Apart from the changes in chemical properties on the experimental plots there are changing also - and favourably too - the physical properties of the soils. They show already after a 2--yearly biological reclamation not a bad soil structure in the 0-20 cm layer. This is being linked with the increase in this zone of organic substance derived from the decayed root mass and from the decomposition of the mowed and abandoned on the surface portions of plants growing above the ground.

7) The comparison of results of the chemical composition analyses of soils and of plants leads to a conclusion that in the reclaimed soils exist factors interfering with the assimilation by plants of some nutrients. This concerns for instance the potassium. The soils occurring on the terrain of the experimental area are being characterized with on the whole an average or even good resourcefulness in the assimilable potassium (table 18). Yet the plants growing on it contained small quantities of this nutrient, and this both on the limed plots, and on the not limed plots. Moreover from the calculated balance of components transpires that the quantity of assimilable potassium contained in the soils before the

introduction of vegetation onto these was higher, than the sum of the potassium derived by the plants and the potassium resident in the soil after the completion of the cycle of experiments. Hence once can deduce, that in the being reclaimed excessively acid soils, exist apart from mechanisms interfering with the potassium assimilation, also factors conducive to its retrogression.

8) The assimilation of magnesium by the plants sown on the experimental plots was also hindered. The content of assimilable magnesium in the soils was high, yet it was low in the vegetable material. The proof of magnesium deficiency gives also the very good crop observed on the micro-plots of the III block, fertilized outside the roots with this element (table 13).

9) On the basis of carried out analyses only in the case of phosphorus there was ascertained a relatinship between its quantity in the soils and in plants. The plants utilized here the phosphorus derived from the ground phosphate rock, introduced into the soils as a neutralizer of toxicity. No handicaps were ascertained in the assimilation of phosphorus on the D combination, where parallel with the ground phosphate rock there was also applied the agricultural ground quicklime, the CaO.

Some chemical properties of the soils on Experimental plots of lignite surface mine "Turów" - 1975

Table 18

Combinations of the neutralization method	Type of fertilization	Depth of sample taking cm	pH reaction in KCl	Hydrolytic acidity, H_h	Replaceable Aluminum Al_r	Content of components dissolvable in 20 % of KCl					Content of assimilables								Yields q/ha	
																			1- swath x/ 7.VII.1975	
						Na_2O	K_2O	CaO	MgO	P_2O_5	K_2O	MgO	P_2O_5	Zn	Cu	Mn	B	Mo	fresh mass	air-dry mass
				mval							mg/100 g			ppm						
A	X_1	0-20	3,9	8,2	2,40	0,02	0,05	0,15	0,10	0,05	16,7	24,5	0,5	26,6	9,7	28,8	0,43	0,44	66,3	31,7
	X_2	0-20	3,8	8,2	2,40	0,02	0,06	0,16	0,11	0,05	16,2	30,8	0,7	30,3	13,6	32,5	0,45	0,50	91,8	41,0
B	X_1	0-20	4,0	4,0	1,00	0,01	0,05	0,18	0,13	0,05	10,5	22,5	1,1	24,3	10,5	21,2	0,32	0,36	105,0	42,0
	X_2	0-20	4,8	2,3	0,50	0,02	0,06	0,26	0,13	0,05	12,5	21,9	1,0	26,6	10,0	18,2	0,47	0,40	92,4	47,1
C	X_1	0-20	5,1	4,2	0,02	0,03	0,04	0,32	0,10	0,05	16,4	24,5	2,6	26,5	9,2	38,8	0,42	0,54	96,7	40,0
	X_2	0-20	4,6	4,0	0,02	0,02	0,04	0,33	0,07	0,05	10,4	21,1	2,0	30,3	9,6	23,8	0,27	0,39	111,2	42,9
D	X_1	0-20	4,6	1,8	0,01	0,02	0,07	0,21	0,14	0,06	17,8	24,9	3,1	25,6	9,1	21,3	0,46	0,45	108,1	59,5
	X_2	0-20	4,6	4,8	0,20	0,03	0,06	0,25	0,13	0,09	21,8	24,9	15,0	32,8	10,1	19,4	0,42	0,41	152,8	78,6
E	X_1	0-20	4,0	4,9	2,20	0,07	0,08	0,15	0,12	0,04	24,4	28,2	5,9	31,4	9,6	17,5	0,51	0,47	90,6	38,2
	X_2	0-20	4,0	6,5	1,20	0,03	0,08	0,16	0,15	0,07	23,9	35,2	6,8	28,7	9,6	20,7	0,55	0,40	94,1	41,7
F	X_1	0-20	3,7	8,1	1,65	0,01	0,05	0,15	0,10	0,07	14,2	19,6	8,6	27,9	9,4	30,0	0,25	0,35	101,8	42,9
	X_2	0-20	3,7	5,9	1,50	0,03	0,06	0,22	0,11	0,08	16,8	30,0	8,4	23,5	10,2	20,3	0,64	0,48	106,2	54,6

x/ average values of 4 repetitions

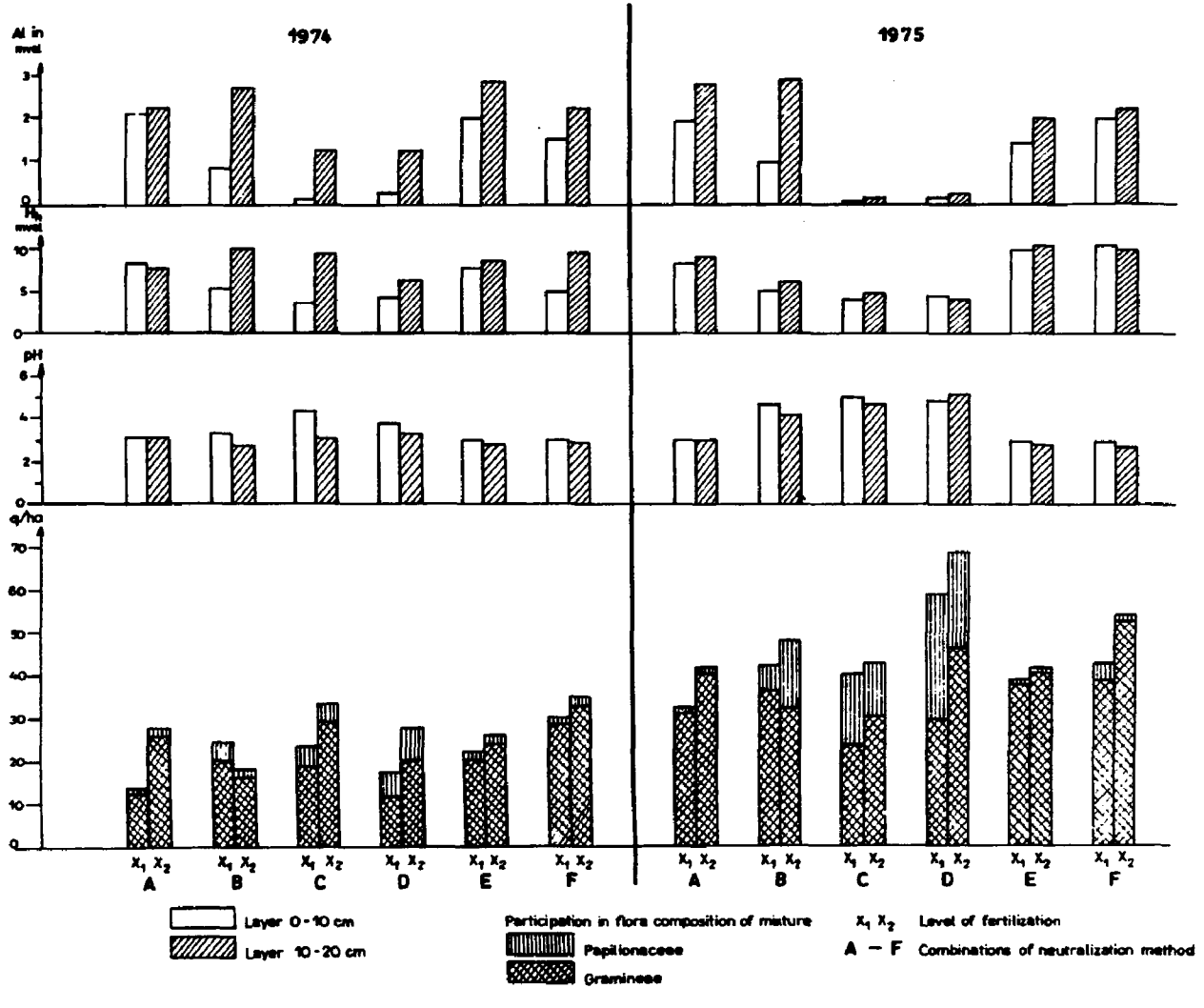


Fig.6 Effects of soils' neutralization and plants' yields.
Experimental plots of the Lignite Surface mine „Turów."

7.4.3.3. The waters.

The experimental plots as already mentioned were set up on a local elevation of an internal stack. In this way these fields could only be watered by a rainwater. The top flat area, the crown, was fashioned in such a way that no water drifting down the slopes was occurring - the top portion was formed so that the downgrade by the slope's verge was made in the direction to the center of the stack area towards the experimental plots. The only spot, where from a local depression of the top area an actual water downtaking was taking place is in a ditch dug out on the northern side of the block III, close to the water sampling station no. 7. In this situation one may consider that no surface water runoff is taking place from the plots set up on the top area and a periodical surplus of water evaporates or percolates deeper down.

The creation of anti - slopes by the verges of the top area protects also the slopes against being eroded by the waters that could be coming from the top. The only erosional washouts that might happen could only occur in the course of water drifts generated by heavy storms, with rain falling directly on the slopes.

On the northern slope within the reach of the S-III block, there the natural water discharges occur. The presence of these outflows proves the existence of local pervious materials, of which is the stack made and also indicates that the flow of waters infiltrating down is mainly is the direction of these discharges. On the remaining slopes no such discharges were observed.

For the performance of observations, necessary to describe the quality of waters as found on this type of disposing stacks, the following stations, of water sampling were set up, where the waters were collected for the analyses: 1-st station - a draining system specially made on the flat top, off the southern part of the block III,
2-nd station - where the surface waters are collected, close to the II block's southern side, on the top area,
3-rd station - surface waters from a local depression continuously being repleted with water coming from a slope shelf, near the S-III block,
4-th station - waters coming from a natural outflow from the upper part of the northern slope beyond the reach of the S-III block,

5-th station - waters coming from a natural outflow occurring on the lower part of northern slope, within the limits of the S-III block - the second in line discharge off the ramp of the access drive,

6-th station - surface waters from a local depression of the terrain, on the slope's shelf, within the reach of the plots of the S-III block,

7-th station - surface waters derived from the top area, on the northern side of the S-III block,

8-th station - waters coming from a natural discharge on a lower part of northern slope occurring within the S-III block limits - the first in line discharge off the drive's ramp to the top area,

9-th, 10-th and 11-th stations - surface waters collected from the upper part of the northern slope from gullies made for the water sampling within the reach of the S-III block,

12-th station - surface waters coming from the upper part of the northern slope, from a gully made to sample waters found outside the plots of the S-III block.

The arrangement of the stations is shown on a drawing. Results of the water samples' analyses are compiled summarily for each station on tables entitled: "Specification of water analyses", which tables are enclosed at the end of this chapter.

The collected water samples were analysed within the scope of the following indices regarded as characteristic: the chlorides, the sulphates, the ammonia nitrogen, the nitrate and nitrite nitrogen, the sodium, the potassium, magnesium calcium, manganese, iron and aluminium - and the indices providing the general qualities of waters such as: reaction, basicity, acidity, hardness, the dissolved compounds, turbidity colour and smell.

The quantity of the specified indicators was determined with the following analytic methods:

- reaction with a potentiometric method,
- basicity in a titration with acid in the presence of methyl orange,
- acidity in a titration method with a sodium hydroxide, using a phenolphthalein as indicator with the determination of an overall (total) acidity and the methyl orange was employed in case when a mineral acidity was occurring,

- chlorides with the Volhard's method,
- sulphates with the method of weighing and with nephelometry,
- ammonia nitrogen with a distillation method using the Nessler reagent,
- nitrate and nitrite nitrogen with the colorimetric method,
- sodium, potassium, calcium with the flame photometric method,
- magnesium, manganese with the method of atomic absorption after a previous mineralization of samples,
- dissolved compounds with the method of vaporization and desiccation of water sample to a state of stable weight, in a temperature of 105°C, soluble mineral compounds in calcination in temperature of 600°C, (total soluble compounds),
- phosphates with a colorimetric method,
- colour was determined through comparisons with the platinum - cobalt reference standards,
- turbidity with phenolmetric method,
- smell by an indirect method according to the 5-grade scale,
- aluminium with a colorimetric method.

The obtained results of tests constituted a basis for the determination of a state of the waters pollution. The source of contamination of these waters are the compounds soluble in water, and contained in the overburden of the lignite deposit of the open pit mine "Turów". On the basis of the waters' composition one must state that the material accumulated on the disposal stack is containing appreciable quantities of easily dissolving acid substances, which proves that the reaction is of waters, particularly of under-ground waters flowing out from natural discharges that have a longest route of filtration in points 5 and 8 and in point no. 12 of the surface water collection.

Waters being in direct contact with substances penetrating from the stack possess an acidity of a mineral character induced by a presence of large amounts of dissolved sulphates of metals. Within the reach of waters stagnating on plots pt. 2.7 the pH value changes from 3.55 to 5.4.

For the surface water in point no. 10 of sampling, the pH attains a value of about 6.8, for point no. 11 it has the 6.4 value, and for point 9 it has the 5.3 value; for the underground water collected in point 4, with its shortest route of filtration the pH value was about 6.6. SO_4 ions occur in very high concentrations of up to 2060 mg/l. Waters coming from the draining system in point no. 1, waters flowing out from the slopes in points 4,5 and 8 and waters stagnating on a shelf in point 6 were marked with a highest content of sulphates - more than 1000 mg/l. A smaller amount of sulphates of about the 1000 mg/l order was ascertained in a water stagnating on the plot 4 in point no. 7 and the smallest one about 500 mg/l was found in waters flowing down the slopes.

The content of chlorides on the whole investigated area fluctuated around the 10 mg/l value. Maximum values are higher than 20 mg/l.

The highest ammonia nitrogen content was found in points of sampling nos. 2,7 and 9. The highest value is obtained in point no. 9 (13 and 17 mg /l). For the remaining points the content of ammonia fluctuates from 0,03 mg/l for the water from the draining system point no. 1, to 6,6 mg/l in the underground water in point no. 5.

The nitrite nitrogen occurs in trace quantities on the investigated area.

Amongst the elements of alkaline soils manifests itself calcium in prevalence over the magnesium.

The established quantities are as follows:

Ca: from 300 mg/l to 500 mg/l for the water from the draining system and from discharges on the slopes about 10 mg/l - 70 mg/l for the remaining points of sampling.

The content of alkaline elements is coming to:

Na: from about 110 mg/l for water from the draining system and from discharges, to about 10 mg/l - 50 mg/l for the remaining points of the water collection,

K: from 30 mg/l to 80 mg/l for water from the draining system and from discharges, and 10 mg/l - 30 mg/l for the remaining points.

Contents of iron and manganese in the region of the investigated points of water collection are as follows:

Fe: from 0,05 mg/l in water from the draining system with a tendency to increase to 6,45 mg/l for the stagnating surface waters on the

plots, and achieves highest values to over 200 mg/l in point 5 of the underground water sampling from natural discharges.

Mn: from about 0,5 mg/l for surface water from point 11 to about 11,9 mg/l for discharge in point 5.

The passing of iron from the soil, in which it is in abundance in a form of pyrite (FeS_2) into natural waters takes place in the course of oxidation or decomposition in a reaction with carbonic acid or other organic acids. In underground waters the iron appears most frequently in a shape of iron bicarbonate or ferrous sulphate. Managanese as a rule occurs together with iron in a form of manganous sulphate, the $MnSO_4$, or as a manganese bicarbonate - the $Mn(HCO_3)_2$. The proportion of manganese to iron concentration in natural waters amounts from 1:5 to 1:10. This rule holds on the whole good also in these investigations, with the exception of water samples from point 8, where the content of iron amounts to over 100 mg/l, and of manganese to 6 - 9 mg/l.

The content of calcium and magnesium salts is the cause of appreciable non-carbonate hardness ($CaSO_4$ and $MgSO_4$). The highest hardness possesses water from the draining system, over 100 German grades. Lowest hardness have surface waters in points 3,9 and 11, having values of 20,25 German grades. For the remaining points of water collection this amounts on average from 50° to 100° German grades.

On account of a very high salinity of the investigated waters, the content of dissolved mineral substances is very high - achieving values from 1500 mg/l to 3000 mg/l for waters from the draining system and from the discharges on the slopes, and to 1300 mg/l for the surface waters.

Physico - chemical properties of the tested surface waters.

Waters within the reach of the stack are characterized with a significant diversification as regards the quantities of investigated pollutant indicators.

With the increase in acidity the content of sulphate ions increases. Content of bicarbonates is very small. Chlorides appear in constant

quantities of about 20 mg/l, indicating no connections with the contents of dominating anions.

Discounting the presence of ammonia derived in underground waters in effect of reclamation activity, the ammonia can also be generated in a reduction of nitrates and nitrites with pyrites and with hydrogen sulphide. In connection with this the waters originating from these sources next to large quantities of iron possess also large amounts of ammonia of a non-organic origin. Quantities of the main cations contained in acid and weakly acid waters, unlike as was the case with sulphates, indicate no clear diversification.

Acidity of a mineral type, causing a low level reaction, facilitates the retention in waters of significant quantities of elements, occurring as microelements in natural conditions.

Moreover, in the course of soils leached out the enrichment of waters takes place with other elements such as iron, manganese and magnesium.

Specification of water analyses

Object **Lignite Mine „Turów"**

Nr of stand and place of taking **● 1–Waters from spec. made drains on the stack flat top from the south side of comp. III**

	Definition	Unit	Date of sampling														
			24.10.74	29.10.74	25.01.75	4.04.75	14.05.75	15.07.75	4.11.75	11.03.75	25.04.75	30.07.75	2.01.75	26.07.75			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	50	50	10	—	—	—	—	—	—	—	—	—			
2	Colour	mg/dm³ Pt	60	40	10	—	40	40	40	35	25	20	50	15			
3	Smell		Z1R	Z1R	Z2S zw. org.	Z1S	Z1S	Z1S	Z3S	Z1S	Z2S	Z2S	Z2S	Z2S			
4	pH value	pH	7.2	6.8	7.1	7.9	6.15	6.85	5.2	7.4	5.6	7.2	5.95	5.75			
5	Basicity	mval/dm³	1.0	0.7	0.8	1.2	0.7	0.75	0.3	—	0.30	0.40	0.35	0.5			
6	Total Hardness	grades	100	103.8	107	107.8	106.8	86.4	61	—	85.0	64.2	39.6	51.2			
7	Non carbonate hardness	grades	97.2	101.84	104.8	104.4	104.8	—	60.5	—	84.2	63.08	38.62				
8	Carbonate hardness	grades	2.8	1.96	2.2	3.4	1.96	—	0.5	—	0.84	1.12	0.98				
9	Total iron Żelazo ogólne	mg/dm³ Fe	—	—	—	0.05	0.15	0.05	0.10	0.17	0.08	0.05	0.01	1.45			
10	Manganese	mg/dm³ Mn			3.2	2.8	5.00	7.75	8.6	5.25	5.75	5.15	4.05	5.20			
11	Chlorides	mg/dm³ Cl	13	11	19.0	13.0	30.0	13.0	11.0	—	6.0	13.0	9.0	12.0			
12	Ammonia	mg/dm³ N	0.56	1.4	0.8	0.06	0.03	0.07	0.30	—	0.05	—	4.75	0.49			
13	Nitrites	mg/dm³ N			0.01	0.001	0.006	0.008	0.008	0.004	0.004	0.005	0.012	0.001			
14	Nitrates	mg/dm³ N		0.07	1.0	0.50	0.75	2.48	0.045	0.05	0.11	0.15	0.91	1.45			
15	Permanganate value	mg/dm³ O_2			9.6	—	10.0	9.0	8.9	6.7	0.8	0.2	0.2	2.4			
16	Mineral acidity	mval/dm³					—	—	—	—	—	—	—	—			
17	Total acidity	mval/dm³					0.50	0.18	0.96	—	0.90	0.17	0.70	0.75			
18	Phospates	mg/dm³ PO_4	0.1	0	0	0.068	0.056	0.110	0.034	0.005	0.026	0.010	0.018	0.026			
19	Total dissolved solids	mg/dm³			2916	3362	2980	2459	1998	—	2025	1857	1984	1444			
20	Mineral dissolved solids	mg/dm³			2858	2978	2610	25.08	17.78	—	1779	727	1736	1242			
21	Substances dissolved volatile	mg/dm³			58	384	370	43	220	—	250	1130	248	202			
22	Sulphates	mg/dm³ SO_4	1768	18.72	2059	1150	1400	14.16	1176	1492	1280	1175	1532	787.5			
23	Calcium	mg/dm³ Ca	433	406.4	470.8	540.0	380.0	245.0	260.0	225.0	210.0	264	144.0	180.0			
24	Magnesium	mg/dm³ Mg	168.5	191.3	174	150.0	7.5	80.0	83.05	5.1	72.5	87.5	57.5	70.0			
25	Sodium (photometr)	mg/dm³ Na		110	140	119.0	66.0	36.0	54.0	63.0	62.5	57.6	40.7	48.5			
26	Potassium (photometr)	mg/dm³ K		80	48.4	57.5	53.0	62.5	32.0	58.5	38.5	49.6	36.7	42.3			
27	Aluminium	mg/dm³ Al					12.2	1.57	—	0.35	3.2	0.25	1.75	0.70			

Specification of water analyses

Object Lignite Mine „Turów"

Nr of stand and place of taking ● 2.- Supef. wt. from top's south side, comp. III

	Definition	Unit	Date of sampling														
			25.07.73	14.09.73	15.07.74	4.11.74	14.01.75	25.04.75	30.05.75	26.07.75							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	15	—	—	—											
2	Colour	mg/dm³ Pt	20	50	70	50	40	40	35	40							
3	Smell		Z2R	Z1S	Z1S	Z2S	Z1S	Z1S	Z1S	Z1S							
4	pH value	pH	4.6	4.95	5.4	5.2	5.1	5.4	4.8	5.9							
5	Basicity	mval/dm³	0.5	0.5	0.40	0.3	0.15	0.25	0.20	0.5							
6	Total Hardness	grades	7.5	41.8	25.6	14.1	11.0	37.0	30.6	15.0							
7	Non carbonate hardness	grades	73.6	40.4	—	13.3	10.58	36.3	30.04								
8	Carbonate hardness	grades	1.4	1.4	—	0.84	0.42	0.70	0.56								
9	Total iron Żelazo ogólne	mg/dm³ Fe	0.4	0.15	0.35	0.05	6.45	0.44	0.10	0.260							
10	Manganese	mg/dm³ Mn	8.12	1.10	2.60	1.8	1.30	1.80	3.60	1.80							
11	Chlorides	mg/dm³ Cl	24.0	14.0	10.0	2.0	5.0	9.0	9.0	10.0							
12	Ammonia	mg/dm³ N	1.98	8.75	1.25	0.34	0.30	3.28	0.16	1.30							
13	Nitrites	mg/dm³ N	0.08	0.016	0.065	0.016	0.006	0.033	0.015	0.330							
14	Nitrates	mg/dm³ N	2.0	6.98	0.01	0.11	0.15	48.5	14.80	4.92							
15	Permanganate value	mg/dm³ O_2	18.0	24.4	19.0	14.1	8.3	1.2	0.3	3.2							
16	Mineral acidity	mval/dm³	—	—	—	—	—	—	—	—							
17	Total acidity	mval/dm³	1.9	0.46	0.35	0.34	0.98	1.39	1.52	0.65							
18	Phospates	mg/dm³ PO_4	0.5	0.062	0.190	0.018	0.005	0.019	0.018	0.032							
19	Total dissolved solids	mg/dm³	2480	1128	838	458	401.0	1250	1031	492							
20	Mineral dissolved solids	mg/dm³	216.5	922	751	378	32.30	925	774	382							
21	Substances dissolved volatile	mg/dm³	3.15	206	87	80	78.0	325	257	110							
22	Sulphates	mg/dm³ SO_4	1582.5	500.0	381	216	241.0	760	460	253.0							
23	Calcium	mg/dm³ Ca	405.6	290.0	110.0	70.0	50.0	157.5	158.0	50.0							
24	Magnesium	mg/dm³ Mg	90.0	75.0	15.50	15.6	4.7	20.0	24.5	15.0							
25	Sodium (photometr)	mg/dm³ Na	35.0	12.0	9.5	28.0	3.0	22.5	21.1	16.0							
26	Potassium (photometr)	mg/dm³ K	35.6	18.0	31.5	4.0	15.0	15.5	33.0	28.5							
27	Aluminium	mg/dm³ Al	—	3.2	2.5	—	5.0	3.5	9.70	1.2							

Specification of water analyses

Object **Lignite Mine „Turów"**

Nr of stand and place of taking **3- Superf. wt from local depression continuously filled with wt on the slope shelf nr comp SIII**

	Definition	Unit	Date of sampling														
			28.12.72	25.01.73	4.04.73	14.05.73	13.07.73	4.11.73	11.03.74	25.04.74	30.05.74	20.11.74	26.07.74				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	10	5	—	—	—	—	—	—	—	—	—				
2	Colour	mg/dm³ Pt	20	5	—	20	25	40	35	20	25	15	10				
3	Smell		Z1R	Z1R	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S				
4	pH value	pH	4.7	4.6	4.6	3.65	5.2	5.4	4.4	4.05	4.4	4.2	4.25				
5	Basicity	mval/dm³	0.1	0.5	—	—	0.30	0.15	—	—	0.20	0.13	0.3				
6	Total Hardness	grades	13.8	41.0	18.4	11.2	24.0	17.8	36.5	53.0	31.2	26.4	22.8				
7	Non carbonate hardness	grades	12.52	39.6	18.4	11.2	—	17.4	36.5	53.0	30.64	26.4	—				
8	Carbonate hardness	grades	0.28	1.4	0.0	0.0	—	0.42	—	—	0.56	0.36	—				
9	Total iron Zelazo ogólne	mg/dm³ Fe	0.33	1.14	1.0	0.50	0.35	0.60	2.70	2.30	0.25	0.70	0.070				
10	Manganese	mg/dm³ Mn		12.6	2.6	1.55	1.60	1.95	5.50	7.00	4.05	3.30	28.0				
11	Chlorides	mg/dm³ Cl	3	0	2.0	20.0	5.0	2.0	3.0	7.0	24.0	5.0	3.0				
12	Ammonia	mg/dm³ N	0.42	0.8	1.4	0.24	0.27	0.06	0.52	0.43	0.19	0.16	0.05				
13	Nitrites	mg/dm³ N		0.01	0.016	0.001	0.010	0.003	0.006	0.003	0.006	0.003	0.005				
14	Nitrates	mg/dm³ N	0.07	0	0.53	0.68	0.49	0.035	0.07	0.19	0.03	0.04	0.05				
15	Permanganate value	mg/dm³ O_2	4.6	4.6	—	4.4	8.2	8.5	5.5	2.4	0.5	0.5	1.2				
16	Mineral acidity	mval/dm³			—	0.20	—	—	0.25	0.12	—	—	—				
17	Total acidity	mval/dm³		2.1	0.45	1.40	0.33	0.55	1.31	1.78	1.17	1.70	0.70				
18	Phospates	mg/dm³ PO_4	0	0	0.001	0.017	0.054	0.013	0.012	0.016	0.010	0.040	0.018				
19	Total dissolved solids	mg/dm³		1322	612	448	658	560.0	1048.0	1258	1023	1603	654				
20	Mineral dissolved solids	mg/dm³		1148	506	308	627	476.0	892.0	1050	841	1409	522				
21	Substances dissolved volatile	mg/dm³		174	106	140	31	84.0	156.0	208	182	194	132				
22	Sulphates	mg/dm³ SO_4	238.6	853.81	202	110	354	340.0	725.0	870	590	1310	5210				
23	Calcium	mg/dm³ Ca	504	185.4	110.0	150.0	100.0	61.5	109.0	157.5	19.4	103.5	82.5				
24	Magnesium	mg/dm³ Mg	28.8	63.0	18.8	55.0	16.25	17.5	5.0	35.0	30.0	27.5	23.75				
25	Sodium (photometr)	mg/dm³ Na	15	48.0	12.4	8.0	8.0	28	22.5	27.0	19.0	10.3	17.5				
26	Potassium (photometr)	mg/dm³ K	5	11.8	10.5	12.0	11.5	7.8	9.0	12.5	14.0	7.5	11.5				
27	Aluminium	mg/dm³ Al	—	—	—	11.5	2.5		7.8	9.7	6.80	4.8	2.65				

Specification of water analyses

Object ..Lignite Mine „Turów"....

Nr of stand and place of taking e.4-Wt from nat. effluent in north slope top part outside the plot-comp S-III range.

	Definition	Unit	Date of sampling														
			29 10.73	25 01.74	4 04.74	14 05.74	15 07.74	4 11.74	11 08.75	25 04.75	30 05.75	2 05.75	25 05.75				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	10	100	—	—	—	—	—	—	—	—	—				
2	Colour	mg/dm³Pt	15	5	—	25	30	60	30	30	30	20	20				
3	Smell		Z1R	Z1R	Z2S	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S	Z2S				
4	pH value	pH	6.7	6.1	6.15	5.85	6.1	6.6	6.2	6.1	6.1	5.4	5.55				
5	Basicity	mval/dm³	0.7	4.7	5.1	0.8	2.2	2.45	2.55	2.0	1.80	0.55	0.6				
6	Total Hardness	grades	58.7	73.0	64.4	71.0	64.0	51.0	60.0	79.0	58.6	61.8	48.4				
7	Non carbonate hardness	grades	54.74	59.8	50.2	68.8	—	44.1	52.85	73.4	54.12	60.28					
8	Carbonate hardness	grades	1.96	13.2	14.2	2.24	—	6.86	7.14	5.6	4.48	1.54					
9	Total iron Żelazo ogólne	mg/dm³Fe	0.28	77.5	43.0	30.5	0.40	1.05	35.00	28.50	8.00	0.80	0.025				
10	Manganese	mg/dm³Mn		4.9	3.8	4.50	4.5	3.15	5.00	5.75	4.65	5.02	3.95				
11	Chlorides	mg/dm³Cl	7	5.0	2.0	58.0	8.0	11.0	10.0	10.0	6.0	12.0	5.0				
12	Ammonia	mg/dm³N	0.56	4.0	1.4	0.84	0.70	0.39	0.24	0.42	0.15	0.12	0.11				
13	Nitrites	mg/dm³N		0	0.008	0.012	0.140	0.018	0.006	0.003	0.001	0.001	0.001				
14	Nitrates	mg/dm³N	0.05	0	0.69	0.43	0.16	0.05	0.29	0.50	0.21	0.05	0.17				
15	Permanganate value	mg/dm³O_2	5.1	110	—	9.6	10.6	6.9	7.5	5.2	1.2	0.5	3.2				
16	Mineral acidity	mval/dm³	—	—	—	—	—	—	—	—	—	—	—				
17	Total acidity	mval/dm³		1.7	—	3.80	0.97	0.54	3.33	4.70	3.73	1.76	1.7				
18	Phospates	mg/dm³PO_4	0	0	0.01	0.008	0.074	0.030	0.005	0.014	0.014	0.018	0.028				
19	Total dissolved solids	mg/dm³		2330	1838	1818	1821	16.82	1813.0	2905	1892	2481	1350				
20	Mineral dissolved solids	mg/dm³		2116	1632	1600	1763	1464	1613.0	1680	1648	2103	1188				
21	Substances dissolved volatile	mg/dm³		214	206	218	58	218	200.0	1225	244	378	162				
22	Sulphates	mg/dm³SO_4	1129	1428	650	794	1120	1082	1186.0	1125	1328	2080	415				
23	Calcium	mg/dm³Ca	256.3	316.4	300.0	320	187.5	220	205.0	225.0	300.0	235.0	175				
24	Magnesium	mg/dm³Mg	87.7	122.2	90.0	20	71.25	75.0	5.2	72.5	75.0	68.8	58.75				
25	Sodium (photometr)	mg/dm³Na	100	13.0	75.0	40	38.0	81.0	56.0	62.5	89.0	61.8	43.0				
26	Potassium (photometr)	mg/dm³K	20.	31.2	48.0	25	26.5	18.9	27.5	28.0	37.0	17.0	18.3				
27	Aluminium	mg/dm³Al	—	—	—	2.6	0.47	—	1.1	1.3	0.35	0.4	0.45				

Specification of water analyses

Object Lignite „Mine Turów"

Nr of stand and place of taking ● S-Wt from natural effl in north bottom slope within the S-III comp.range-second effluent from ramp side

	Definition	Unit	Date of sampling														
			29 10.73	21 01.74	4 04.74	14 05.74	15 07.74	4 11.74	11 03.75	25 04.75	30 05.75	2 07.75	28 07.75				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	30	1000	—	—	—	—	—	—	—	—	—				
2	Colour	mg/dm³ Pt	15	30	—	25	20	35	30	40	30	20	20				
3	Smell		Z1R	Z1R	Z1S	Z1S	Z1S	Z1S	Z1R	Z1R	Z1S	Z1S	Z1S				
4	pH value	pH	3.8	4.5	4.8	3.75	3.85	3.7	4.55	3.75	3.55	3.4	3.7				
5	Basicity	mval/dm³	0	0.1	0.6	—	—	—	0.15	—	—	—	—				
6	Total Hardness	grades	64.5	47.6	59.6	58.0	54.8	52.0	41.0	55.0	45.4	42.4	2.56				
7	Non carbonate hardness	grades	64.5	47.3	57.9	58.0	—	52.0	40.56	55.0	45.4	42.4	—				
8	Carbonate hardness	grades	—	0.3	1.7	0.0	—	—	0.42	—	—	—	—				
9	Total iron Żelazo ogólne	mg/dm³ Fe	4.46	225.0	8.4	21.5	0.40	3.20	29.75	3.90	3.00	3.60	0.02				
10	Manganese	mg/dm³ Mn		11.9	5.4	6.40	8.25	10.5	6.25	7.25	5.90	6.75	4.10				
11	Chlorides	mg/dm³ Cl	11	0	11.0	28.0	15.0	9.0	4.0	11.0	11.00	7.0	8.0				
12	Ammonia	mg/dm³ N	0.95	6.6	0.48	0.03	0.30	0.17	0.17	0.06	0.19	0.17	0.08				
13	Nitrites	mg/dm³ N		0.1	0.009	0.001	0.001	0.045	0.004	0.015	0.009	0.007	0.003				
14	Nitrates	mg/dm³ N	0.05	0	0.89	0.22	0.06	0.004	0.20	0.16	0.07	0.06	0.08				
15	Permanganate value	mg/dm³ O_2	5.8	80		16.8	8.2	3.9	17.5	2.0	0.5	0.5	1.2				
16	Mineral acidity	mval/dm³	0.5			0.38	0.47	0.12	—	0.30	0.57	0.38	0.30				
17	Total acidity	mval/dm³		1.1		3.10	1.38	2.58	4.25	2.00	2.23	1.92	1.5				
18	Phospates	mg/dm³ PO_4	0.1	0	0.002	0.026	0.092	0.034	0.030	0.018	0.034	0.006	0.020				
19	Total dissolved solids	mg/dm³		2376	1559	1574	1571	1562	1627.0	1443	1548	2285	756				
20	Mineral dissolved solids	mg/dm³		1941	1450	1376	1557	1392	1404.0	1268	1316	1915	622				
21	Substances dissolved volatile	mg/dm³		535	208	198	14	170.0	223.0	175	232	370	134				
22	Sulphates	mg/dm³ SO_4	1104	1509	650	710	1000	1126.0	1080.0	902	1008	1800	297.5				
23	Calcium	mg/dm³ Ca	284.7	208.2	340.0	290	200.0	270	170.0	157.5	250.0	169.0	100.5				
24	Magnesium	mg/dm³ Mg	104.9	82.8	70.0	17.5	50.0	67.5	5.2	37.5	48.5	55.0	25.0				
25	Sodium (photometr)	mg/dm³ Na	15	90.0	10.0	26.0	17.0	44.0	34.5	46.5	45.0	47.0	24.0				
26	Potassium (photometr)	mg/dm³ K	5	25.2	25.5	31.0	24.0	13.0	20.0	18.0	26.0	20.0	15.8				
27	Aluminium	mg/dm³ Al				7.5	8.0	—	5.1	5.0	6.30	6.0	2.2				

Specification of water analyses

Object **Lignite Mine „Turów"**

Nr of stand and place of taking **8 5-Superf .wt from local terrain depression on the slope shelf within the plot comp S-III range**

	Definition	Unit	Date of sampling															
			29 10.73	25 01.74	4 04.74	14 05.74	15 07.74	4 11.74	11 08.75	25 04.75	30 05.75	2 07.75	28 07.75				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	10	400	—	—	—	—	—	—	—	—	—				
2	Colour	mg/dm³ Pt	10	5	—	35	60	35	35	30	25	25	20				
3	Smell		Z1R	Z2R	Z1S	Z1S	Z2S	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S				
4	pH value	pH	6.5	4.6	4.65	3.85	6.8	6.45	6.1	5.3	6.7	6.3	4.8				
5	Basicity	mval/dm³	0.2	0.1	—	—	1.0	0.25	0.25	0.20	0.75	0.90	0.3				
6	Total Hardness	grades	54.3	53.0	105.6	54.0	58.4	65	49.0	85.0	60.0	58.6	30.8				
7	Non carbonate hardness	grades	53.74	52.7	105.6	54.0	—	64.3	48.30	84.4	57.90	56.08					
8	Carbonate hardness	grades	0.56	0.3	0	0.0	—	0.7	0.70	0.56	2.10	2.52					
9	Total iron Żelazo ogólne	mg/dm³ Fe	0.06	0.48	0.55	1.10	0.10	0.05	0.03	0.08	0.05	0.01	0.035				
10	Manganese	mg/dm³ Mn		8.12	6.7	2.30	3.05	6.3	3.10	5.85	2.05	3.95	3.55				
11	Chlorides	mg/dm³ Cl	9	0.0	7.5	23.0	9.0	4.0	7.5	6.0	5.0	6.00	3.0				
12	Ammonia	mg/dm³ N	0.42	2.0	3.78	2.98	0.50	0.18	0.03	0.07	0.15	0.13	0.05				
13	Nitrites	mg/dm³ N		0.04	0.02	0.010	0.005	0.01	0.003	0.004	0.002	0.001	0.007				
14	Nitrates	mg/dm³ N	0.07	0.2	2.18	2.87	0.05	0.025	0.04	0.07	0.03	0.03	0.11				
15	Permanganate value	mg/dm³ O_2	6.2	3.0	—	23.2	13.8	9.3	7.9	1.2	0.5	0.4	1.6				
16	Mineral acidity	mval/dm³			—	0.30	—	—	—	—	—	—	—				
17	Total acidity	mval/dm³		1.1	1.0	1.60	0.19	0.74	0.17	0.52	0.2	0.14	0.8				
18	Phospates	mg/dm³ PO_4	0	0.09	0.001	0.052	0.090	0.018	0.018	0.010	0.020	0.010	0.030				
19	Total dissolved solids	mg/dm³		1684	2834	1096	1687	1798	1582.0	1918	1696	2148	906				
20	Mineral dissolved solids	mg/dm³		1525	2020	946	1585	1596	1388.0	1704	1672	2009	746				
21	Substances dissolved volatile	mg/dm³		159	632	150	102	202	174.0	214	324	409	160				
22	Sulphates	mg/dm³ SO_4	1034	1121	1010	470	1056	1260	1070.0	1255	1342	1896	385.5				
23	Calcium	mg/dm³ Ca	247	171.0	430.0	280.0	190.0	280	177.0	205.0	267.0	195.0	115.0				
24	Magnesium	mg/dm³ Mg	82.9	630	122.5	65	537.5	80.0	5.2	63.8	47.5	92.5	35.0				
25	Sodium (photometr)	mg/dm³ Na	70	67.0	95.0	12	38.5	64.0	50.5	67.0	114.0	71.0	27.0				
26	Potassium (photometr)	mg/dm³ K	15	17.4	31.4	13	19.0	8.0	14.5	20.0	16.0	17.0	12.0				
27	Aluminium	mg/dm³ Al				11.5	0.65	—	0.7	1.9	0.30	0.45	3.15				

Specification of water analyses

Object **Lignite Mine „Turów"**

Nr of stand and place of taking **7 - Superf wt from top flat on the north side of comp III**

	Definition	Unit	Date of sampling														
			25 01.74	4 04.74	14 05.74	15 07.74	4 11.74	11 03.75	25 04.75	30 05.75	2 07.75	28 07.75					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	10	—	—	—	—	—	—	—	—	—					
2	Colour	mg/dm³ Pt	5	—	30	50	50	35	30	35	30	15					
3	Smell		Z1R	Z1S	Z1S	Z1R	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S					
4	pH value	pH	4.6	4.9	3.4	3.55	5.1	5.4	5.25	4.5	5.5	6.35					
5	Basicity	mval/dm³	0.1	0.8	—	—	0.15	0.20	0.20	0.25	0.25	0.6					
6	Total Hardness	grades	49.0	50.0	32.8	15.2	16.2	7.6	18.2	17.2	20.8	16.8					
7	Non carbonate hardness	grades	48.7	47.8	32.8	—	15.8	7.04	17.6	16.50	20.10	—					
8	Carbonate hardness	grades	0.3	2.2	0.0	—	0.42	0.56	0.56	0.70	0.70	—					
9	Total iron Zelazo ogólne	mg/dm³ Fe	0.18	0.47	0.15	0.40	0.05	0.17	0.50	0.15	0.02	0.025					
10	Manganese	mg/dm³ Mn	0.70	3.0	2.25	1.25	1.45	0.67	1.65	1.90	1.65	0.65					
11	Chlorides	mg/dm³ Cl	0.0	8.5	36.0	7.0	4.6	3.0	10.0	5.0	6.0	2.0					
12	Ammonia	mg/dm³ N	1.6	4.22	13.1	0.32	0.48	0.38	0.33	0.21	0.16	0.07					
13	Nitrites	mg/dm³ N	0.01	0.025	0.015	0.017	0.017	0.007	0.018	0.009	0.001	0.009					
14	Nitrates	mg/dm³ N	0.2	2.07	5.99	0.55	0.07	0.02	0.28	0.02	0.04	0.08					
15	Permanganate value	mg/dm³ O_2	4.3	—	17.6	18.6	9.3	7.5	2.4	0.4	0.5	1.2					
16	Mineral acidity	mval/dm³	—	—	0.40	5.92	—	—	—	—	—	—					
17	Total acidity	mval/dm³	2.1	—	1.48	4.02	0.52	0.48	0.69	0.5	0.31	0.2					
18	Phospates	mg/dm³ PO_4	0.0	0.001	0.075	0.150	0.030	0.016	0.008	0.010	0.008	0.048					
19	Total dissolved solids	mg/dm³	1554	1412	1213	835	492	262.0	57.1	568.0	1201	452					
20	Mineral dissolved solids	mg/dm³	1406	1114	1021	425	412	204.0	47.9	438.0	1010	336					
21	Substances dissolved volatile	mg/dm³	148	298	192	410	80	58.0	92.0	130.0	191	116					
22	Sulphates	mg/dm³ SO_4	918	320	252	506	264	127.0	340	279	840	257.0					
23	Calcium	mg/dm³ Ca	268.8	250.0	200.0	75.0	61.5	30.0	62.5	65.0	70.5	62.5					
24	Magnesium	mg/dm³ Mg	50.0	27.5	10.0	10.0	11.25	4.5	7.5	10.5	11.3	60.0					
25	Sodium (photometr)	mg/dm³ Na	25.0	21.5	9.0	2.0	9.2	3.7	10.6	9.4	2.3	8.0					
26	Potassium (photometr)	mg/dm³ K	15.8	19.5	13.0	18.5	4.95	2.9	7.4	6.3	5.5	10.8					
27	Aluminium	mg/dm³ Al	—	—	7.7	2.9	—	2.5	3.6	2.55	1.65	0.20					

Specification of water analyses

Object Lignite Mine „Turów"

Nr of stand and place of taking ● 8-Waters from nat. effluent in the north bottom slope within the comp S-III first effluent from the ramp side

	Definition	Unit	Date of sampling															
			4 04.74	14 05.74	15 15.07	4 11.74	11 03.75	25 04.75	30 05.75	2 07.75	28 07.75							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	—	—	—	—	—	—	—	—	—							
2	Colour	[illegible] Pt	—	50	60	80	50	40	30	30	40							
3	Smell		Z2S	Z2S	Z2S	Z1S	Z1S	Z1S	Z2S	Z1S	Z2S							
4	pH value	pH	3.95	3.45	3.1	3.45	4.25	3.95	3.1	3.5	3.3							
5	Basicity	mval/dm³	—	—	—	—	—	—	—	—	—							
6	Total Hardness	grades	62.0	50.0	58.0	47.0	49.0	62.0	46.4	52.8	68.0							
7	Non carbonate hardness	grades	62.0	50.0	—	47	49.0	62.0	46.4	52.8								
8	Carbonate hardness	grades	0.0	0.0	—	—	—	—	—	—	—							
9	Total iron Zelazo ogólne	mg/dm³Fe	154.0	107.5	126.0	191.0	185.0	171.25	78.75	29.50	0.015							
10	Manganese	mg/dm³Mn	5.9	6.20	7.25	7.4	7.00	7.25	6.65	8.75	6.50							
11	Chlorides	mg/dm³Cl	8.0	16.0	13.0	13.0	9.0	21.0	10.0	14.0	13.5							
12	Ammonia	mg/dm³N	0.12	3.90	1.05	0.49	0.31	0.19	0.52	0.40	0.21							
13	Nitrites	mg/dm³N	0.009	0.006	0.030	0.002	0.005	0.003	0.014	0.004	0.014							
14	Nitrates	mg/dm³N	1.29	1.39	0.77	0.53	0.08	1.72	0.29	0.74	0.15							
15	Permanganate value	mg/dm³O_2	—	14.8	28.2	46.1	41.1	34.0	2.6	3.1	27.6							
16	Mineral acidity	mval/dm³	—	0.80	3.72	0.31	0.18	0.48	0.51	0.46	1.0							
17	Total acidity	mval/dm³	—	8.80	8.60	14.7	13.5	13.8	9.0	7.8	0.3							
18	Phospates	mg/dm³PO_4	0.016	0.106	0.068	0.013	0.026	0.016	0.018	0.010	0.016							
19	Total dissolved solids	mg/dm³	2282	1842	2245	1962	2182.0	2133.0	2182	2500	1984							
20	Mineral dissolved solids	mg/dm³	1740	1544	1976	1504	1655.0	1703.0	1806	2125	1494							
21	Substances dissolved volatile	mg/dm³	542	298	266	458	527.0	430.0	376	375	470							
22	Sulphates	mg/dm³SO_4	660	786	1400	1340	1394.0	1430	1440	2080	1242.5							
23	Calcium	mg/dm³Ca	275.0	290	167.5	190.0	157.0	162.5	225.0	172.0	160.0							
24	Magnesium	mg/dm³Mg	80.0	15	65.0	82.5	5.2	52.5	65.0	60.0	75.0							
25	Sodium (photometr)	mg/dm³Na	42.0	26	23.0	52.0	51.0	52.0	67.0	57.0	60.0							
26	Potassium (photometr)	mg/dm³K	20.5	22	21.2	18.1	16.3	17.0	23.0	22.5	21.8							
27	Aluminium	mg/dm³Al	—	17.5	9.1	—	5.1	7.7	6.90	3.8	4.25							

Specification of water analyses

Object **Lignite Mine „Turów"**

Nr of stand and place of taking **Φ 9 - Superf. wt. from north slope top part gulley nr 1 to wt taking within the comp. S-III range.**

	Definition	Unit	Date of sampling															
			14 05.74	13 07.74	30 05.75	2 07.75	26 07.75											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	—	—	—	—	—										
2	Colour	mg/dm³ Pt	35	35	20	30	30										
3	Smell		Z1S	Z1S	Z2S	Z2S	Z1S										
4	pH value	pH	4.0	4.4	5.3	5.0	5.2										
5	Basicity	mval/dm³	—	0.2	0.25	0.20	0.3										
6	Total Hardness	grades	20.8	21.6	27.8	8.0	2.6										
7	Non carbonate hardness	grades	20.8	—	27.10	7.44	—										
8	Carbonate hardness	grades	0.0	—	0.70	0.56	—										
9	Total iron Żelazo ogólne	mg/dm³ Fe	0.40	0.10	0.07	0.01	0.060										
10	Manganese	mg/dm³ Mn	1.15	2.05	1.40	0.35	0.35										
11	Chlorides	mg/dm³ Cl	24.0	7.0	7.0	5.0	12.0										
12	Ammonia	mg/dm³ N	13.2	17.5	1.87	10.9	1.83										
13	Nitrites	mg/dm³ N	0.010	0.100	0.040	0.076	0.072										
14	Nitrates	mg/dm³ N	5.99	2.30	10.30	2.05	2.73										
15	Permanganate value	mg/dm³ O_2	10.0	9.4	0.4	0.8	1.2										
16	Mineral acidity	mval/dm³	0.24	—	—	—	—										
17	Total acidity	mval/dm³	1.30	1.08	0.77	0.38	0.35										
18	Phospates	mg/dm³ PO_4	0.224	0.080	0.005	0.005	0.019										
19	Total dissolved solids	mg/dm³	568	612	970	1131	178										
20	Mineral dissolved solids	mg/dm³	430	371	768	1037	110										
21	Substances dissolved volatile	mg/dm³	118	41	202	144	68										
22	Sulphates	mg/dm³ SO_4	170	306	428	860	65.5										
23	Calcium	mg/dm³ Ca	180	80.0	130.0	175.0	25.0										
24	Magnesium	mg/dm³ Mg	10	15.75	30.0	3.3	2.75										
25	Sodium (photometr)	mg/dm³ Na	10	3.5	36.0	0.5	5.0										
26	Potassium (photometr)	mg/dm³ K	15	14.5	14.0	8.0	12.0										
27	Aluminium	mg/dm³ Al	7.0	7.5	1.95	1.3	0.75										

Specification of water analyses

Object **Lignite Mine „Turów"**

Nr of stand and place of taking ● 10-Superf. wt from north slope top part gulley nr2 to wt taking within the comp.S-III range.

	Definition	Unit	Date of sampling															
			14 05.7%	15 07.7%														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	—	—													
2	Colour	mg/dm³ Pt	80	70													
3	Smell		Z1S	Z2S													
4	pH value	pH	6.45	6.80													
5	Basicity	mval/dm³	0.7	1.55													
6	Total Hardness	grades	52.8	38.2													
7	Non carbonate hardness	grades	50.8	—													
8	Carbonate hardness	grades	1.96	—													
9	Total iron Żelazo ogólne	mg/dm³ Fe	0.15	0.25													
10	Manganese	mg/dm³ Mn	0.75	1.35													
11	Chlorides	mg/dm³ Cl	20.0	8.0													
12	Ammonia	mg/dm³ N	0.54	0.40													
13	Nitrites	mg/dm³ N	0.28	0.001													
14	Nitrates	mg/dm³ N	4.32	0.19													
15	Permanganate value	mg/dm³ O_2	11.6	15.2													
16	Mineral acidity	mval/dm³	—	—													
17	Total acidity	mval/dm³	0.30	0.19													
18	Phospates	mg/dm³ PO_4	0.048	0.048													
19	Total dissolved solids	mg/dm³	1246	928													
20	Mineral dissolved solids	mg/dm³	1010	838													
21	Substances dissolved volatile	mg/dm³	236	90													
22	Sulphates	mg/dm³ SO_4	410	506													
23	Calcium	mg/dm³ Ca	290	125													
24	Magnesium	mg/dm³ Mg	14	18.25													
25	Sodium (photometr)	mg/dm³ Na	11	10.0													
26	Potassium (photometr)	mg/dm³ K	12	9.5													
27	Aluminium	mg/dm³ Al	1.3	1.25													

Specification of water analyses

Object **Lignite Mine „Turów"**

Nr of stand and place of taking ● 11-Superf wt from north slope top part gulley nr.3 to wt taking within the comp. S-III range.

	Definition	Unit	Date of sampling														
			14 05.74	15 07.74	30 05.75	26 07.75											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	—	—	—	—											
2	Colour	mg/dm³ Pt	50	40	30	25											
3	Smell		Z1S	Z1S	Z2S	Z2S											
4	pH value	pH	5.25	6.2	6.4	6.05											
5	Basicity	mval/dm³	0.2	0.5	0.65	0.4											
6	Total Hardness	grades	26.8	13.6	44.4	4.2											
7	Non carbonate hardness	grades	26.2	—	39.58	—											
8	Carbonate hardness	grades	0.56	—	1.82	—											
9	Total iron Żelazo ogólne	mg/dm³ Fe	0.35	0.10	0.08	0.050											
10	Manganese	mg/dm³ Mn	0.85	0.50	1.55	0.20											
11	Chlorides	mg/dm³ Cl	16.0	7.0	4.0	10.0											
12	Ammonia	mg/dm³ N	2.65	0.45	0.21	1.14											
13	Nitrites	mg/dm³ N	0.020	0.040	0.058	0.45											
14	Nitrates	mg/dm³ N	4.24	0.91	1.13	0.33											
15	Permanganate value	mg/dm³ O_2	12.0	9.0	0.5	2.4											
16	Mineral acidity	mval/dm³	—	—	—	—											
17	Total acidity	mval/dm³	0.60	0.13	0.36	0.2											
18	Phospates	mg/dm³ PO_4	0.038	0.105	0.026	0.040											
19	Total dissolved solids	mg/dm³	634	336	1322	242											
20	Mineral dissolved solids	mg/dm³	526	303	1088	148											
21	Substances dissolved volatile	mg/dm³	108	33	234	94											
22	Sulphates	mg/dm³ SO_4	160	370	792	67.0											
23	Calcium	mg/dm³ Ca	20.0	55.2	200.0	25.0											
24	Magnesium	mg/dm³ Mg	5.0	7.25	32.5	2.00											
25	Sodium (photometr)	mg/dm³ Na	10	2.0	45.0	4.0											
26	Potassium (photometr)	mg/dm³ K	12	7.0	16.0	11.3											
27	Aluminium	mg/dm³ Al	3.3	0.97	0.30	0.40											

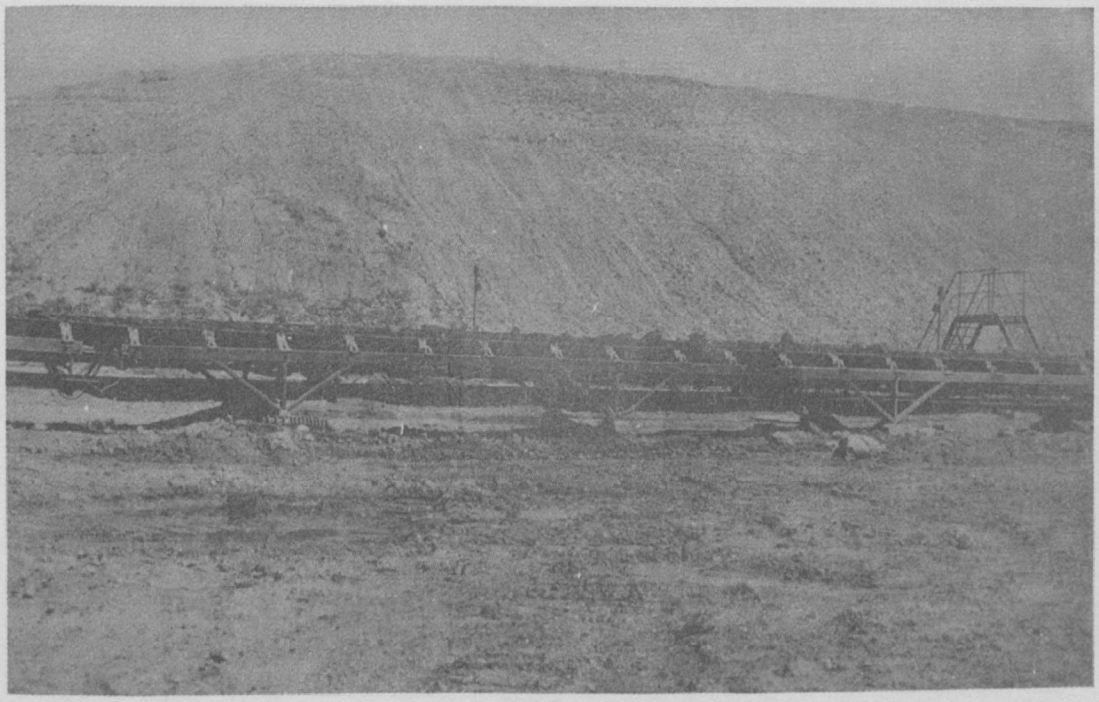
Specification of water analyses

Object **Lignite Mine „Turów"**

Nr of stand and place of taking ● 12-Superf waters from north slope top part from gulley nr 4 for wt taking outside the plot-comp.S-II

	Definition	Unit	Date of sampling															
			14 05.74	15 07.74	30 05.75	2 07.75	28 07.75											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	—	—	—	—	—											
2	Colour	mg/dm³ Pt	30	40	20	50	25											
3	Smell		Z1S	Z1S	Z1S	Z2S	Z1S											
4	pH value	pH	3.9	3.5	4.7	4.3	4.7											
5	Basicity	mval/dm³	—	—	0.40	0.25	0.3											
6	Total Hardness	grades	44.2	90.8	74.0	40.8	28.0											
7	Non carbonate hardness	grades	41.2	—	72.88	40.10	—											
8	Carbonate hardness	grades	0.0	—	1.12	0.70	—											
9	Total iron Żelazo ogólne	mg/dm³ Fe	2.25	3.40	0.06	0.05	0.035											
10	Manganese	mg/dm³ Mn	5.20	16.75	8.70	6.50	2.15											
11	Chlorides	mg/dm³ Cl	10.0	6.0	15.0	9.0	8.0											
12	Ammonia	mg/dm³ N	1.63	0.90	0.81	0.95	0.12											
13	Nitrites	mg/dm³ N	0.006	0.019	0.008	0.009	0.02											
14	Nitrates	mg/dm³ N	0.69	0.23	0.05	0.15	0.03											
15	Permanganate value	mg/dm³ O_2	17.2	6.6	0.2	0.2	2.4											
16	Mineral acidity	mval/dm³	0.20	1.25	—	—	—											
17	Total acidity	mval/dm³	2.10	3.71	2.0	1.72	0.80											
18	Phospates	mg/dm³ PO_4	0.032	0.098	0.026	0.019	0.056											
19	Total dissolved solids	mg/dm³	1132	2836	2266	1917	824											
20	Mineral dissolved solids	mg/dm³	934	2726	1914	1964	650											
21	Substances dissolved volatile	mg/dm³	198	110	352	153	194											
22	Sulphates	mg/dm³ SO_4	450	1864	1440	1640	505.0											
23	Calcium	mg/dm³ Ca	260	257.6	371.0	155.0	100.5											
24	Magnesium	mg/dm³ Mg	18	85.5	75.0	61.3	27.5											
25	Sodium (photometr)	mg/dm³ Na	16	33.0	48.0	24.5	16.5											
26	Potassium (photometr)	mg/dm³ K	9	23.5	21.0	12.5	14.3											
27	Aluminium	mg/dm³ Al	13.4	19.5	9.20	10.5	2.90											

7.4.4. PHOTOGRAPHIC DOCUMENTATION.

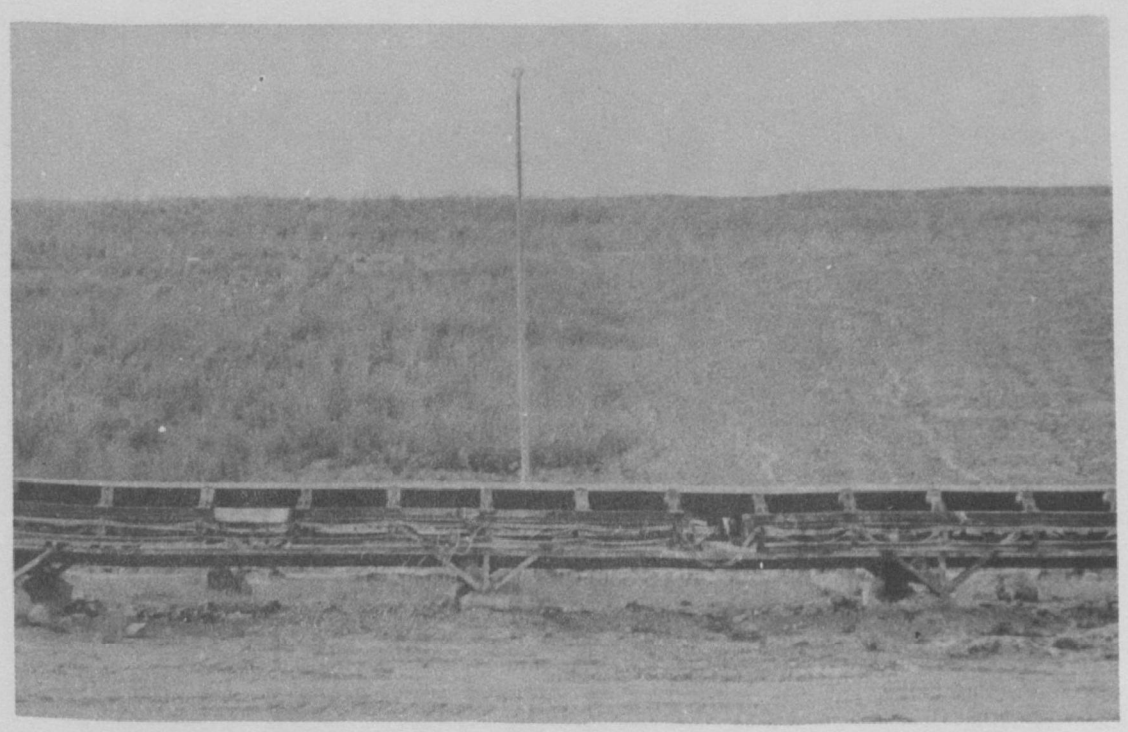


North-western corner; plots on the western slope on the right.

Erosive washings on the north western corner.

View of the slopes after formation.

View of the top portion after sowing



General view of experimental plots on the slope.

View of vegetation in 1974 growing on the experimental plots set on the top portion - of the plots on the II block and of investigated neutralization and fertilization combinations photos on the pages 107 - 112.


cm
40
30
20
10
T II E X0


cm
40
30
20
T II E X1


cm
40
30
20
10
T II E X2


T II A X0


T II A X1


T II A X2


cm
40
30
20
T II D X0


cm
40
30
20
T II D X1


cm
40
30
20
T II D X2


T II C X0


T II C X1


T II C X2

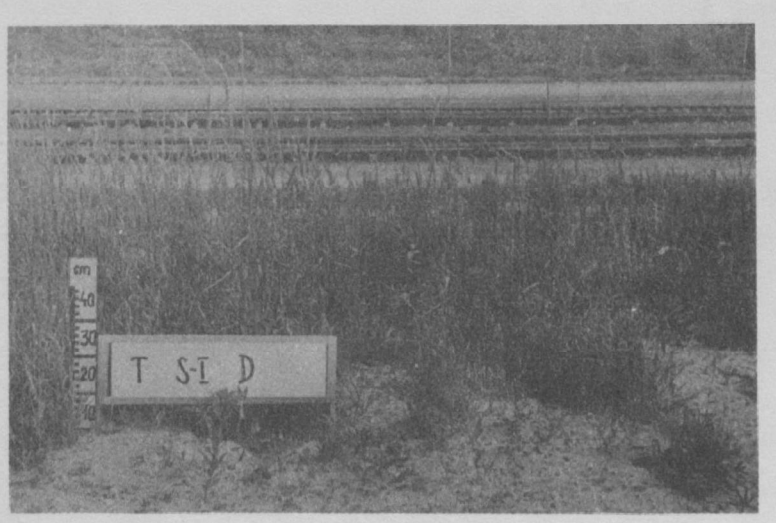

cm
40
30
20
10
T II B X0


cm
40
30
20
T II B X1


T II B X2

View of vegetation growing in 1974 on experimental plots set on the slope - blocks - I and tested combinations of neutralization - photos on the pages 113 - 114.


cm
40
30
20
10
T S-I C


cm
40
30
20
10
T S-I D

7.5. General characteristics of the lignite surface mine "Przyjaźń Narodów".

On the terrains of the lignite surface mine "Przyjaźń Narodów" the extraction operations have ended few years ago - the profitable resources of lignite have been exhausted. The lignite seam of miocene age was occurring in a form of narrow synclines on the depth from few to about 50 meters. The overburden constituted mainly fine grained sands or loamy sands.
The overburden was worked with dragline excavators and directly dumped into the internal stack. The lignite was excavated by means of shovel excavators and transported by the rail directly to the nearby situated briquetting plant. Here after its moulding it was supplied to the consignees. In the effect of so conducted exploitation the obtained worked out terrains have small diversification in respect of altitude. The main areas are the inner spoil disposals and the final reservoirs. The small areas of external stack are the gently undulated surfaces inclining towards the final excavations. Presently the activity on the mine is being limited to the performance of reclamation work.

7.6. The report of the research work carried out on the experimental plots localized on an internal stack of the lignite surface mine "Przyjaźń Narodów".

The experimental plots are localized on an almost levelled out flat north - eastern part of the internal stack. The area on which the plots were set up has the direction of general inclination towards the final excavation filled with water and is situated somewhat below the level of natural terrain. This area is situated, at a distance of 80 km from Turów in the northern direction.

7.6.1. The characteristics of the habitat conditions on the experimental plots.

7.6.1.1. The characteristic of soils.

In order to prepare a pedological and chemical - agricultural documentation of soils of the experimental plots, set up on an internal stack were tested 64 samples. These samples constituted an average of few points from every plot, and were taken from 4 depths, i.e. 0-10, 10-20, 20-30 and 30-40 cm. Each sample represents a corresponding plot i.e. one plot represents one combination of the method of neutralization, and simultaneously the 3 ways of applied biological lining.

The results of laboratory tests of physical and chemical properties are compiled on the table 19 from which transpires, that the soils occurring in this area are hardly diversified.

Considering the granulation of soils represented by 64 samples one has to state, that these constitute mainly sands, as only one sample contained a mild clay. According to the classification of soils as adopted by the Polish Pedological Association, the diversification of the granulometric composition presents itself as follows:

4 samples	sands lightly clayey
49 samples	light clayey sands
3 samples	rich clayey sands
1 sample	light clay

From this transpires also the equal content of particles 0,002 mm, the quantity of which fluctuates within the 5-8 %. A quantitative prevalence indicates fraction 0,1 - 0,25 mm diam. These soils lack the fraction diam. 1,0 mm occurring here only exceptionally. In the mineral composition of the considered soils prevails quartzite, occurring mainly in a form of sharp edged grains of a diameter 0,1 - 0,25 mm. Amongst the particles of the silty fraction prevails kaolinite. There is very little minerals from the illite group, and where are present they form bands with the montmorillonite. Also ascertained was the presence of small quantities of feldspars. Almost in all samples there occurs the carbon substance, mainly in a form of comminuted lignites and xylites.

Specification of the analytical research results of soil investigations
on the spoil stack
Experimental plots KWB "Przyjaźń Narodów" - 1974

Table 19

Designations	Unit	from	to	Average	Remarks
Content of skeleton ϕ 1 mm	% weight	0	1,7	0	
Content of organic substance (Lignites, xylites)	% weight	0,0	1,0 - 2,5		
Particles content					
1,0 - 0,1	mm	62	87	66 - 80	Casagrade areometric method in Prószyński modification fraction 1,0 - 0,1 mm with the sievemethod
0,1 - 0,25		65	83	70-77	
0,25- 0,5		0	14	1-5	
0,5 - 0,1		0		0	
0,1 - 0,05	mm	1	21	10 - 15	
0,05 - 0,02	mm	1	4	1 - 4	
0,02 - 0,002	mm	1	10	5 - 8	
<0,002	mm	2	15	5 - 8	
Maximal capillary water capacity	% weight	21,0	30,1	23 - 27	
Field water capacity	% weight	19,5	27,6	21 - 25	
Filtration	cm/hour	0,5	10,5	2 - 6	after 24 hours
Maximal higroscopity	% weight	0,6	2,3	1 - 1,5	
Specific gravity	g/cm^3	2,60	2,67	2,62 - 2,67	
Weight by volume	g/cm^3	1,28	1,50	1,34 - 1,43	pouring
Porosity	%	42,7	51,1	45 - 48	
pF pore of ϕ > 38	u	6	45	10 - 26	
38 - 39	u	6	55	30 - 40	
<9	u	17	88	25 - 40	
Methylen blue sorption	mval/100 g	1,6	5,5	3,5 - 4,5	
Reaction in H_2O	pH	2,4	4,0	2,8 - 3,2	potentiometric
in KCl	pH	2,4	4,0	2,8 - 3,2	
Hydrolitic acidity H_h	mval/100 g	5,1	15,8	8,0 - 12,0	
Exchangable acidity H_w	mval/100 g	0,1	2,0	0,2 - 0,5	
Exchangable aluminium Al_w	mval/100 g	2,2	13,5	6,0 - 10,0	
S - total, in this:	% weight	0,2	0,9	0,3 - 0,5	
SO_4^{-2} in form of salt	mg/100 g	56,0	356,2	100 - 180	
SO_4^{-2} in form of free H_2SO_4	mg/100 g	0,0	61,3	10 - 30	
Content of soluble components in 20 % HCl					
Na_2O	% weight	0,01		0,01	
K_2O	- " -	0,01	0,06	0,02 - 0,04	
MgO	- " -	0,01	0,07	0,02 - 0,04	
CaO	- " -	0,04	0,13	0,05 - 0,10	
Fe_2O_3	- " -	0,41	0,89	0,50 - 0,80	
P_2O_5	- " -	0,01	0,02	0,01 - 0,02	
Content of components in a form assimilable by plants					
K_2O	mg/100 g	1,3	4,5	1,8 - 3,0	
P_2O_5	mg/100 g	0,2	0,7	0,3 - 0,5	
N - general	%	0,03	0,06	0,03	Denoted only in 0-10 cm layer

The soils of the experimental plots are characterized with a considerable permeability a small sorptive capacity and a small resourcefulness into the plant nutrients. In the tertiary formations superimposed on the lignite seams there occur significant amounts of sulphates. In the course of exploitation, and stacking these undergo a fast oxidation and they do not occur on the stack as a rule. Characteristic however is the presence of the products of their decomposition, and amongst them of the free A_2SO_4, which causes the reaction of soils to be toxically acid. In natural conditions, the spoils of this mine are completely deprived of vegetation derived from natural succession.

7.6.1.2. Characteristic of atmospheric precipitations.

The characteristic of atmospheric precipitation was prepared on the basis of observations performed in a meteorological station situated at a distance of 2 km from the experimental plots. Compiled on the table are average and extreme values of monthly and yearly sums of precipitations, determined from the observation period 1950 - 1972 and also the monthly and yearly sums of precipitations recorded in the years 1973 - 1975. Moreover, similarly as in the case of Turów, the distribution of daily precipitations for the period of time of performed research the data were marked on the comprehensive diagram of carried out observations and treatments.

From the values given on the table transpires, that the most advantageous year for the vegetation was the year 1974, during which in the summer period the amount of precipitations was higher or only slightly lower than average values. Only in April the precipitation was considerably lower than average, which only a little belated the early growth of plants. The year 1975 must be considered as a very unfavourable for the vegetation. There occurred only few precipitations in the following months: February, March, May, June, September. These low precipitations and the lack of rainfall for several days during the remaining months of the vegetation period was very difficult for the plants particularly when growing on sandy soils.

Specification of characteristic values of precipitations for the precipitation station Łęknica

Table 20

Period year	Months Rainfall in mm	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
From the period 1950 - 1972	Sums:													
	Average	41	38	38	46	61	66	75	76	50	44	44	44	629
	Maximum	76	75	70	86	155	133	229	132	137	115	88	88	841
	Minimum	12	4	15	11	17	14	16	14	4	7	13	6	416
1973	Sums	27,7	47,7	24,1	96,3	63,7	43,0	161,1	64,7	22,7	64,4	44,8	72,0	732,2
1974	Sums	39,6	47,1	28,0	13,7	109,4	81,3	62,7	68,6	55,5	193,2	75,1	179,8	953,5
1975	Sums	53,9	13,8	22,6	54,8	42,2	32,2	96,5	79,9	21,1	58,0			

7.6.1.3. The characteristic of air temperature.

Owing to the fact, that the temperature is a climatic factor less changeable than is precipitation the observations carried out in Zgorzelec station (40 km to S) were utilized for the characterization of the air temperatures. The average values of temperatures are given and discussed in the point 7.4.1.2.

7.6.1.4. The characteristic of atmospheric air pollution.

In the region of Łęknica there are no industrial enterprizes that could pollute the atmosphere, and therefore the problem of air pollution has nobearing on the acquired results of research work.

7.6.2. Reclamation work.

7.6.2.1. Neutralization.

The treatments of neutralization pertaining to the excessive soil acidification were performed during the months November 1973 - January 1974. Used as neutralizers were two substances in various doses:

1) the magnesia (magnesium oxide) lime being a waste product from the production of zinc,the chemical composition of which is presented in approximation as follows:

CaO	40 %
MgO	20 %
Fe_2O_3	12 %
SiO_2	9 %

the remainder constitute Al_2O_3, S and a number of microelements.

2) the ground phosphate rock containing about 40 % of $CaCO_3$, and 30 % of P_2O_5.

On the experimental plots the following combinations of neutralization were used:

A. magnesia lime in a dose of 25 t/ha, in one layer, on 16 plots of a total area 0,5 ha

B. magnesia lime in a dose 50 t/ha, in one layer, on 16 plots of total area 0,5 ha

C. magnesia lime in dose 50 t/ha, in two layers:

0 - 20 cm 40 t/ha
20 - 40 cm 10 t/ha
16 plots of a total area 0,5 ha

D. magnesia lime in a dose 45 t/ha and ground phosphate rock in a dose 5 t/ha, in two layers:

0 - 20 cm magnesia lime 40 t/ha
20 - 40 cm magnesia lime 5 t/ha and ground phosphate rock 5 t/ha
16 plots of a total area 0,5 ha.

So the experimental area involved 64 plots of a total area 2,0 ha (fig. 7).

A detailed description of a method of neutralizers introduction was given in a report of investigations performed in the second stage in 1974. The treatments connected with this activity contained:

1) Spreading out of magnesia lime on 16 plots of a combination A,B,C,D, i.e. on a total area 2,0 ha.

2) Spreading out of ground phosphate rock on 16 plots of the D combination, i.e. of a total area 0,5 ha.

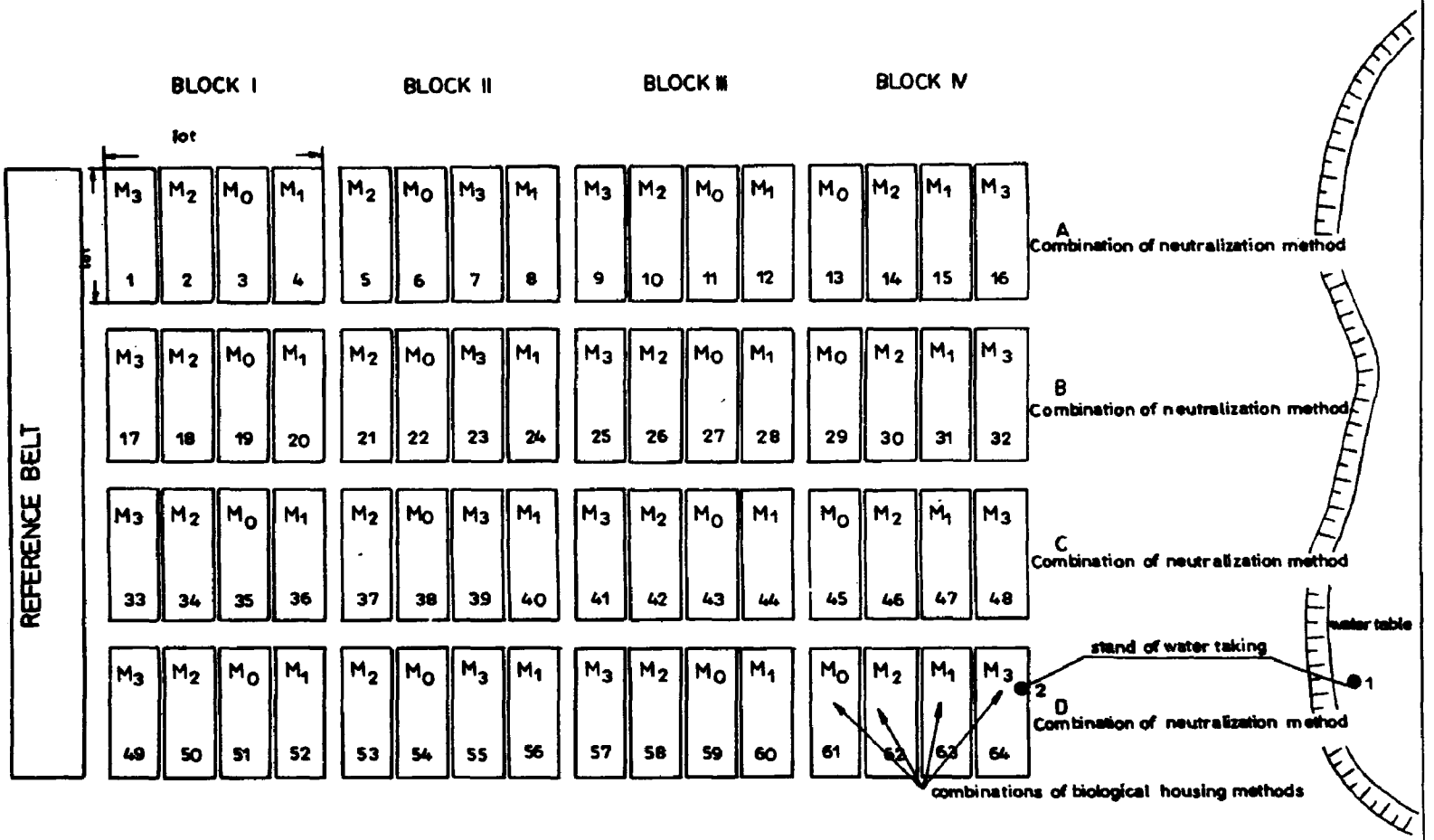
3) Twice done tilling with a roto-tiller of 32 plots of the C, D combination i.e. on a total area of 1,0 ha.

4) Ploughing accomplished on 32 plots of C, D combination, i.e. on a total area of 1,0 ha.

5) Sowing out of the remaining dose of magnesia lime on 32 plots of C, D combination, on a total area 1,0 ha.

6) Four times done tillage with a roto-tiller on the entire experimental area, i.e. on 64 plots of a total area 2,0 ha.

Fig.7 SCHEME OF EXPERIMENTAL PLOTS ON INTERNAL DUMPING GROUND OF THE LIGNITE MINE „PRZYJAŹŃ NARODÓW"



PAGE NOT

AVAILABLE

DIGITALLY

7.6.2.2. Mineral fertilization.

On the whole experimental area a uniform NPK mineral fertilization was applied. Doses and forms of introduced fertilizers in particular years were specified on table 21.
The employed mineral fertilization was augmented in relation to the assumed amount in the plan of experiments, that was elaborated in 1974 year. In particular increased was the dose of nitrogen by 50 kg/ha, phosphorus by 20 kg/ha, phosphorus by 20 kg/ha, and potassium by 35 kg/ha. The premise to increase the doses of fertilizer amounts were the observations made on the growth and the health of plants, and also the results of chemical analyses of soils and vegetation from adjacent terrains, already restored in previous years.

Mineral fertilization employed on experimental plots of the Lignite Surface Mine "Przyjaźń Narodów"

Table 21

Fertilizing component	Doses and forms of mineral fertilizers used in years	
	1974	1975
N	200 kg/ha nitro-chalk 25 % i.e. 50 kg/ha N	300 kg/ha nitro-chalk 25% i.e. 75 kg/ha N
P	150 kg/ha superphosphate 18 % i.e. 12 kg/ha P	255 kg/ha superphosphate 18 % i.e. 20 kg/ha P
K	100 kg/ha potash salt 60 % i.e. 50 kg/ha K	180 kg/ha potash salt 40% i.e. 60 kg/ha K

During a two - yearly period of conducted research on the disposal of the Lignite Surface Mine "Przyjaźń Narodów", i.e. in the years 1974 - 1975, the treatments connected with fertilization involved the following operations:

in 1974

1) Sowing out of potash salt and nitro-chalk on the whole experimental area, i.e. on 64 plots of a total area 2,0 ha.

2) Harrowing of the whole experimental area, i.e. on 64 plots of a total area 2,0 ha.

3) Sowing out of superphosphate on the whole experimental area, i.e. on 64 plots of a total area 2,0 ha.

4) Harrowing of the entire experimental area, i.e. of 64 plots of a total area 2,0 ha.

in the year 1975

1) Spreading out the potash salt and nitro-chalk on the whole experimental area, i.e. on 64 plots of a joint area 2,0 ha.

2) Harrowing the whole experimental area i.e. of 64 plots of a total area 2,0 ha.

3) Sowing out superphosphate on the whole experimental area, i.e. on 64 plots of a total area 2,0 ha.

4) Harrowing the whole experimental area, i.e. of 64 plots of total area 2,0 ha.

5) Sowing out the potash salt and nitro-chalk on the whole experimental area, i.e. on 64 plots of an area 2,0 ha.

6) Harrowing the whole experimental area of 64 plots with a total area of 2,0 ha.

7) Sowing out superphosphate on the whole experimental area, i.e. on 64 plots of total area 2,0 ha.

8) Harrowing the whole experimental area of 64 plots, of a total area 2,0 ha.

7.6.2.3. Introduction of vegetation.

Within the limits of the experimental area three kinds of a biological lining with a herbaceous vegetation were applied, and namely:

Mo without sowing on of any vegetation seeds, 16 plots of a total area equalling 0,5 ha.

M_1 mixture no. 1 of papilionaceae with grasses, 16 plots of a total area 0,5 ha.

M_2 mixture no. 2 of papilionaceae with grasses, 16 plots of a joint area 0,5 ha

M_3 mixture no. 2 of papilionaceae with grasses, 16 plots of a joint area 0,5 ha.

The species composition of the mixtures appeared as follows:

Mixture no,1

Sundial lupine (Lupinus polyphyllus)	30 kg/ha
Redtop (Agrostis alba)	8 kg/ha
Tall ryegrass (Arrhenatherum elatius)	6 kg/ha
Meadow fescue (Festucca pratensis)	6 kg/ha
together	50 kg/ha

Mixture no,2

Birdsfoot trefoil (Lotus corniculatus)	20 kg/ha
Smooth bromegrass (Bromus inermis)	8 kg/ha
Dutch ryegrass (Lolium multiflorum westerwaldicum)	6 kg/ha
Meadowgrass (Poa pratensis)	6 kg/ha
together	40 kg/ha

Mixture no,3

White clover (Trifolium repens)	10 kg/ha
White melilot (Melilotus Albus)	5 kg/ha
Timothy grass (Phleum pratense)	8 kg/ha
Italian ryegrass (Lolium multiflorum)	6 kg/ha
Creeping fescue (Festuca rubra)	6 kg/ha
together	35 kg/ha

The treatments connected with the introduction of vegetation and its cultivation comprized the following operations:

in year 1974

1) Sowing out of mixtures no. 1, 2 and 3 on 48 plots with a total area 1,5 ha.

2) Harrowing and rolling of the entire experimental area, i.e. the 64 plots of a total area 2,0 ha.

in the 1975 year

1) Harrowing the entire experimental area, i.e. the 64 plots of total area 2,0 ha

2) Mowing with a mower - cutter the entire experimental area on the 20-th of June, 64 plots of a total area 2,0 ha.

7.6.3. Assessment of effects of reclamation work carried out on the Lignite Surface Mine "Przyjaźń Narodów".

In order to determine the effects of reclamation operations, there were made apart from the usual current observations of vegetation and a systematic control of the neutralization progress and a periodical assessment performed of the soils' resourcefulness in nutrients, also the following operations:

in the year 1975

1) The determination of the size of crops - I swath in the second ten day period of month June.

2) Sample taking of the vegetative material in order to determine the chemical composition - June.

3) Visual estimation of the green growth floristic composition - June.

4) Measurement of the root systems of papilionaceous plants from the introduced mixtures - the third decade of June.

7.6.3.1. Vegetation.

On the flat top part of the spoil stack there were set up experimental plots in 1973, where various combinations of the neutralization methods were used. These plots were being sown over by 3 mixtures of papilionacea mixed with grasses, of following compositions:

Mixture M_1

Lupinus polyphyllum	30 kg/ha
Agrostis alba	8 kg/ha
Arrenatherum elatius	6 kg/ha
Festuca pratensis	6 kg/ha
together	50 kg/ha

Mixture M_2

Lotus corniculatus	20 kg/ha
Brome inermis	8 kg/ha
Lolium multiflorum westerwaldicum	6 kg/ha
Poa pratensis	6 kg/ha
together	40 kg/ha

Mixture M_3

Trifolium repens	10 kg/ha
Melilotus albus	5 kg/ha
Phleum pratense	8 kg/ha
Lolium multiflorum westerwaldicul	6 kg/ha
Festuca rubra	6 kg/ha
together	35 kg/ha

Owing however to the difficult soil conditions and to the unfavourable distribution of atmospheric precipitation recorded in 1974, the first crop from the plots was collected only in 1975, and only 1 swath, as the drought made impossible the regrowth of the green growth. Results of a visual evaluation of vegetation development (growth, compactness, green growth appearance), on plots with particular combinations of the neutralization method, are being specified on the table 22. The best valuation results acquired mixtures sown out on plots of the D combination. This method of neutralization influenced

most advantageously the flora composition of the green growth, as a highest rate of the papilionaceous plants participation was apparent in it (Table 23).

The carried out observations permitted to formulate the following conclusions regarding suitability of the being introduced species for a biological lining of the disposals that have characteristics approximating the ones obtaining on the spoil stack of the Lignite Surface Mine "Przyjaźń Narodów".

Results of a visual evaluation of vegetation growth - carried out in June of 1975 x/

Experimental plots of the Lignite Surface Mine "Przyjaźń Narodów" 1975

Table 22

Combinations of the neutralization method \ Mixture of plants	M_0	M_1	M_2	M_3
A	2	2	2	2
B	3	2	2	2
C	3	3	2	3
D	4	4	4	4

x/ - average from the block I - IV

M_0 - plot not sown over (control)

M_1, M_2, M_3 - mixtures of papilionaceous plants with grasses.

Scale of appreciation

5 growth very good
4 growth good
3 growth average
2 growth poor
1 growth bad

Participation of grasses and papilionaceae in green growth dependent on the method of neutralization and species composition of the employed mixture of grasses with papilionaceae.

Experimental plots of the Lignite Surface Mine "Przyjaźń Narodów"- 1975

Table 23

Neutralization Combinations	Mixture of plant seeds / Plant	M_1	M_2	M_3
		% participation in green growth		
A	Gramineae:	95	85	98
	Lupinus polyphyllus	5	-	-
	Lotus corniculatus	-	15	-
	Trifolium repens	-	-	2
B	Gramineae:	95	79	98
	Lupinus polyphyllus	5	-	-
	Lotus corniculatus	-	21	-
	Trifolium repens	-	-	2
C	Gramineae:	92	82	97
	Lupinus polyphyllus	8	-	-
	Lotus corniculatus	-	18	-
	Trifolium repens	-	-	3
D	Gramineae:	78	71	79
	Lupinus polyphyllus	22	-	-
	Lotus corniculatus	-	-	-
	Trifolium repens	-	-	21

1) Among the tested species of papilionaceous plants the best suitability and usefulness exhibited the Lupinus polyphyllus. Its health was good, it was giving a comparatively large mass of the above ground and the below the surface portions. The main root mass was reaching to a depth of 20 cm, therefore not so deep as on the plots of the Lignite Surface Mine "Turów".

2) Of the remaining species of Papilionaceae, both Lotus corniculatus and Trifolium repens also developed well, but the Melilotus albus only very poorly. It's roots were strongly deformed and were reaching not deep.

3) Amongst the tested out species of Gramineae the best suitability have indicated the Agrostis alba and the Lolium multiflorum westerwoldicum. The remaining sorts also were growing not badly, whereby the surveillance of reclaimed portions of the disposal before the 1974 was showing that after few years among the Gramineae, there the Agrostis alba, the Festuca rubra and the Phleum pratense began to prevail distinctly.

4) Most advantageously influenced the size crops the D and C neutralization combinations, whereby the highest crops were attained from M_1 and M_2 mixtures. On the whole, however, the crops were low, all the more so, as no further swaths were collected, as it was usual during years with a normal number of days with atmospheric precipitation (table 24).

5) Linked closely with the biomass above the ground is the development and the reach of biomass from under the surface. It appears from the table 25, that the weight of the root systems of Lupinus and Lotus was even higher than the weight of the developed above the ground mass of the mixture.

6) The vegetable material from the plots is being characterized by a low content of K, Ca and N.
Somehow low put for S, P and Cu, on the other hand rather good for Mg and Zn and put a little high for Fe and Mn (table 26).
In the mixtures of herbaceous vegetation, there is a lack of more pronounced differences in the contents of particular components,

Amount of crops and chemical composition of plants, dependent on the neutralization method and the species composition of the mixture of papilionaceous plants with grasses.

Experimental plots of the Lignite Surface Mine "Przyjaźń Narodów" - 1975.

Table 24

Combinations of the neutralization method	Mixture of plants	Crop yields g/ha		Content in a dry mass of the plant mixture										
		Swath I x/		Macrocomponents %							Microcomponents %			
		Fresh mass	Air - dried mass	Na	K	Ca	Mg	P	N	S	Zn	Cu	Mn	Fe
A	M_0	15,8	5,7	0,02	1,5	0,2	0,2	0,26	1,3	0,2	35	4	282	300
	M_1	25,1	8,5	0,02	1,6	0,2	0,2	0,26	1,3	0,2	35	5	383	440
	M_2	14,4	5,3	0,01	1,2	0,3	0,2	0,27	1,1	0,2	35	1	247	570
	M_3	20,4	8,4	0,02	1,3	0,3	0,2	0,25	1,0	0,2	33	3	295	460
B	M_0	23,0	8,3	0,01	1,6	0,2	0,2	0,26	1,2	0,2	32	4	294	280
	M_1	29,6	11,8	0,01	1,6	0,2	0,2	0,26	1,0	0,2	32	1	478	350
	M_2	11,4	7,7	0,02	1,3	0,3	0,2	0,30	1,0	0,1	34	3	280	445
	M_3	19,2	10,0	0,02	1,3	0,3	0,2	0,28	1,1	0,1	35	2	425	505
C	M_0	19,9	7,6	0,01	1,6	0,2	0,2	0,26	1,2	0,2	32	5	344	390
	M_1	34,8	15,6	0,01	1,5	0,2	0,2	0,22	1,1	0,2	32	traces	420	385
	M_2	15,7	6,8	0,01	1,3	0,3	0,2	0,25	1,3	0,1	35	5	225	560
	M_3	32,4	14,3	0,02	1,6	0,3	0,2	0,28	1,1	0,2	36	5	440	285
D	M_0	25,4	11,2	0,01	1,6	0,2	0,2	0,37	1,3	0,2	32	5	275	370
	M_1	40,9	15,5	0,01	1,6	0,3	0,3	0,37	1,1	0,2	36	7	380	484
	M_2	27,8	11,4	0,01	1,4	0,3	0,3	0,33	1,3	0,2	37	2	185	560
	M_3	40,8	15,5	0,04	1,3	0,3	0,2	0,40	1,3	0,2	43	4	400	380

Notice: Due to unfavourable weather conditions only one swath had been collected.

x - average value from 4 repetitions

* - species composition of the mixtures is compiled on the table

Weight of root - mass of papilonaceous plants dependent on the neutralization method - 2-nd year of vegetation

Experimental plots of the Lignite Surface Mine "Przyjaźń Narodów" - 1975.

Table 25

Plant mixture	Species composition of the mixture	Combinations of the neutralization method Weight of root mass q/ha	A			B			C			D		
			Lupinus polyphyl.	Lotus cornic.	Trifolium repens	Lupinus polyphyl.	Lotus cornic.	Trifolium repens	Lupinus polyphyl.	Lotus cornic.	Trifolium repens	Lupinus polyphyl.	Lotus cornic.	Trifolium repens
M_1	Lupinius polyphyllus Agrostis alba Arrenatherum elatius Festuca pratensis	Fresh mass	79,0	-	-	52,0	-	-	35,0	-	-	35,0	-	-
		Air-dried mass	27,9	-	-	16,9	-	-	10,6	-	-	11,6	-	-
M_2	Lotus corniculatus Bromus inermis Lolium multiflorum Poa pratensis	Fresh mass	-	55,0	-	-	85,0	-	-	51,0	-	-	28,0	-
		Air-dried mass	-	21,3	-	-	33,1	-	-	19,2	-	-	9,4	-
M_3	Trifolium repens Melilotus albus Phleum pratense Lolium multiflorum Festuca rubra	Fresh mass	-	-	20,0	-	-	14,0	-	-	10,0	-	-	15,0
		Air-dried mass	-	-	6,6	-	-	4,5	-	-	2,6	-	-	3,9

however it seems, that the D combination of neutralization method has shown itself as the best. The vegetation from these plots namely characterizes a lightly higher content of macro- and microelements. Also on the plots of the D combination, the plants derived largest amounts of nutritious components (table 26).

7.6.3.2. S o i l s.

In order to determine the effects of soils' neutralization and the plants' fertilizer requirements, samples of soils were taken from experimental plots in the year 1975. The average results of the pedological chemical analyses were shown on figure 9 and on tables 24 and 27.

The estimation of changes in soils characteristics in the effect of employed neutralizers on experimental plots of the Lignite Surface Mine "Przyjaźń Narodów" affords certain difficulties. It is being linked with a very weak buffering of sandy soils by the neutralizers. The presence, for example, in a taken for tests soil sample of a not decomposed lump of lime, used for the neutralization, distorts also the results of chemical analyses, and not only of reaction, and in consequence may lead to an erroneous evaluation of reclamation results. Taking into consideration these limitations, one can, on the basis of acquired results, formulate the following conclusions:

1) After the introduction of neutralizers into the soil a rapid but of short duration alkalization of top layers occurs, and after the withdrawal of it, the differences among the chemical characteristics of soils placed on the 0 - 10 and 10 - 20 cm depths are decreasing. This proves that a displacement of lime compounds from the surface into deeper layers is taking place.

2) All the combinations of the neutralization method of excessive soils' acidification employed on the plots were materially raising the reaction (pH) in the layer 0 - 20 cm, were depressing the hydrolytic acidity (H_h), and decreasing the content of replaceable aluminium (Al_w). It is difficult to select here one of the employed combinations of neutralization as definitely the best. It seems, that both the B and the D combinations are the very good ones.

3) Similarly as on the experimental area of the Lignite Surface Mine "Turów", little marked was the dependence between the effects of neutralization expressed by pH, H_h and Al_r changes and the change of plants' growth conditions, as manifested by the crops. Based on the size of crops one can ascertain the superiority of the two component combined neutralization.

4) On the experimental plots of the Lignite Surface Mine "Przyjaźń Narodów", there were, with the exception of D combination, surfaces occurring of land not covered by any vegetation. On the plots of A combination these occupied about 10 % of area, on the B combination about 5 %, and on C combination about 3 % of the plots' area. The analytic tests of soil samples taken from places deprived of vegetation have shown that the cause of this was first of all the continuing toxically acid soil reaction, fluctuating from 2,6 to 2,9 pH.

5) It was ascertained on the experimental plots of Lignite Surface Mine "Przyjaźń Narodów" the occurrence of more explicit relationships than was the case on the experimental area of the "Turów" Lignite Surface Mine, between the chemical composition of soils and the vegetation (table 24 and 27).
The put low contents of potassium in plants are linked with its low content in the subsoil, and also with big concentration of Ca^{2+} and Mg^{2+} ions, impeding the assimilation of this constituent. Owing to the application of magnesia lime (magnesium oxided lime) as a neutralizer, both in soils and in plants good Mg content was ascertained.

6) No phosphorus famine was observed in the vegetation, despite the trace amounts only of this element in the soils. Possibly a certain role in mobilizing this component played large biomass of underground portions of the many species mixtures of papilionaceous plants mixed with grasses.

7) The analysis of contents of some trace elements in the soils of the disposal indicated the not bad content of Zn and an average one of Mo, and a somehow put low Cu and B, and also low Mn

Quantity of components assimilated by the above the ground portions of plants, dependent on the neutralization method and on species composition of the used mixture of papilionaceous plants with grasses.

Experimental plots of the Lignite Surface Mine "Przyjaźń Narodów" - 1975

Table 26

Combinations of the neutralization method	Mixture of plants	Yields q/ha		Quantity of components assimilated with the yield of the I swath of hay in kg/ha										
		I swath x/ 7.VII.1975		macro - components							micro - components			
		Fresh mass	Air-dried mass	Na	K	Ca	Mg	P	N	S	Zn	Cu	Mn	Fe
A	M_0	15,8	5,7	0,1	8,6	1,1	1,1	1,5	7,4	1,1	0,02	0,002	0,16	0,17
	M_1	25,1	8,5	0,2	13,6	1,7	1,7	2,2	11,1	1,7	0,03	0,004	0,33	0,37
	M_2	14,4	5,3	0,1	6,4	1,6	1,1	1,4	5,8	1,1	0,02	0,001	0,13	0,30
	M_3	20,4	8,4	0,2	10,9	2,5	1,7	2,1	8,4	1,7	0,03	0,002	0,25	0,39
B	M_0	23,0	8,3	0,1	13,3	1,7	1,7	2,2	10,0	1,7	0,03	0,003	0,24	0,23
	M_1	29,6	11,8	0,1	18,9	2,4	2,4	3,1	11,8	2,4	0,04	0,001	0,56	0,41
	M_2	11,4	7,7	0,2	10,0	2,3	1,5	2,3	7,7	0,8	0,03	0,002	0,22	0,34
	M_3	19,2	10,0	0,2	13,0	3,0	2,0	2,8	11,0	1,0	0,04	0,002	0,43	0,51
C	M_0	19,9	7,6	0,1	12,2	1,5	1,5	2,0	9,1	1,5	0,02	0,004	0,26	0,30
	M_1	34,8	15,6	0,2	23,4	3,1	3,1	3,4	17,2	3,1	0,05	traces	0,66	0,60
	M_2	15,7	6,8	0,1	8,8	2,0	1,4	1,7	8,8	0,7	0,02	0,003	0,15	0,38
	M_3	32,4	14,3	0,3	22,9	4,3	2,9	4,0	15,7	2,9	0,05	0,007	0,63	0,41
D	M_0	25,4	11,2	0,1	17,9	2,2	2,2	4,1	14,6	2,2	0,04	0,006	0,31	0,41
	M_1	40,9	15,5	0,2	24,8	4,7	4,7	5,7	17,1	3,1	0,06	0,011	0,59	0,75
	M_2	27,8	11,4	0,1	16,0	3,4	3,4	3,8	14,8	2,3	0,04	0,002	0,21	0,64
	M_3	40,8	15,5	0,6	20,2	4,7	3,1	6,2	20,2	3,1	0,07	0,006	0,62	0,59

x/ average values calculated from 4 repetitions

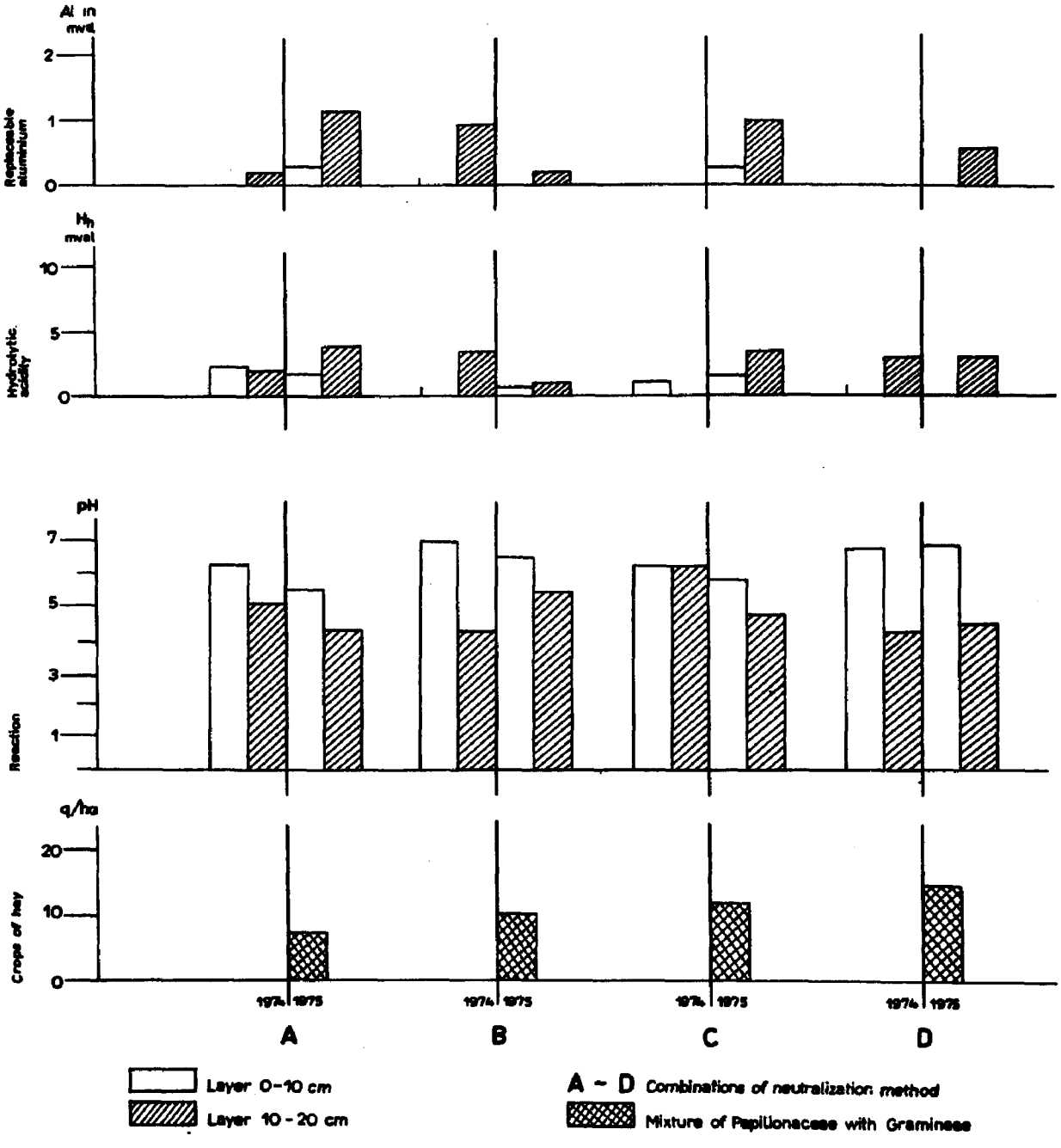


Fig 9 Effects of soils' neutralization and plants' yields. Experimental plots of the Lignite Surface Mine the „Przyjaźń Narodów".

Some chemical properties of soils.

Experimental plots of the Lignite Surface Mine "Przyjaźń Narodów" - 1975

Table 27

Combinations of the neutralization method	Depth of the sample taking, cm	pH in KCl	Hydrolytic acidity H_h	Replaceable aluminium Al_r	N general %	Content of assimilables								Yields q/ha	
														I swath x/ 7.VII.1975	
						K_2O	MgO	P_2O_5	Cu	Zn	Mn	B	Mo	Fresh mass	Air-dried mass
			mval			mg/100 g			ppm						
A	0 - 20	5,7	2,26	0,00	0,02	4,0	38,6	0,7	2,4	18,2	3,8	0,16	0,19	18,9	7,0
B	0 - 20	6,4	1,30	0,00	0,02	4,2	38,8	0,5	2,3	15,1	2,5	0,14	0,19	20,8	9,5
C	0 - 20	5,9	2,20	0,01	0,03	3,7	44,8	0,2	2,1	11,1	3,8	0,16	0,18	25,7	11,1
D	0 - 20	6,5	4,04	0,02	0,02	4,1	47,9	5,5	2,4	19,8	3,8	0,15	0,22	33,7	13,4

x/ - average values calculated from 4 repetitions

content. Most probably the liming, connected with neutralization of excessively acid soils of this disposal, is the cause of the low content occurrence of some trace elements in the form assimilable to the plants.

7.6.3.3. The waters.

In order to characterize the quality of waters and the impact of reclamation treatments on the water quality two stations were assigned for the water samples' taking for the analyses.

Station 1 - Surface water from the final excavation working filled with water.

Station 2 - Specially executed draining system, intaking the waters, that percolated through a layer of soil of a thickness about 1 m.

The surface waters' sampling was practically impossible on account of a considerable permeability of formations from which the stack was made. The surface water was occurring only for a short duration and only during the periods of rains of great intensity or during the times of very early spring with long lasting precipitations.
Rains of great intensity were causing the formation of erosion washings on areas not grown over with vegetation, and which were inclined a little. The flowing water through these washings was a mixture of soil and water, and not a polluted water. The results of analyses of taken water samples are specified on tables.
Water from the draining system was initially very strongly acidified with the pH - 2,8, with large content of total iron - 115 mg/dm^3, with manganese 3,8 mg/dm^3, aluminium - 1986 mg/dm^3 and a very large content of dissolved substances, mainly mineral matter and sulphates.

Probably, in the effect partly of performed reclamation treatments completed, and partly through a leached out from soils certain quantity of compounds, an improvement took place in the parameters of the pollutants. Especially distinctly advantageous changes occurred in the following indicators:

pH	-	increased to 4,0
total iron	-	decreased to 0,020 mg/dm^3
mineral acidity	-	decreased to 0,6 $mval/dm^3$
dissolved solids	-	decreased to 692 mg/dm^3
sulphates	-	decreased to 447 mg/dm^3
aluminium	-	decreased to 5,0 mg/dm^3.

In reference to water from the final excavation no such so clearly advantageous change was noted. This water was characterized with a good stability of particular parameters of pollutants, the variation of which seems to depend mainly on the season of the year and on the water content of the reservoir. Furthermore, it looks as if the reclamation treatments carried out on the surface of the terrain, even the ones placed very close to the final excavation working would have only a small impact on the quality of waters in this reservoir.

Specification of water analyses

Object **Lignite Mine „ Przyjaźń Narodów"**

Nr of stand and place of taking **1-Waters from final reservoir**

	Definition	Unit	Date of sampling														
			25.1.74	4.04.74	14.04.74	18.07.74	2.11.74	11.12.74	20.04.75	30.05.75	2.07.75	25.07.75					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	15	—	—	—	—	—	—	—	—	—					
2	Colour	mg/dm³ Pt	5	—	20	20	30	30	20	20	15	30					
3	Smell		Z1R	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S	Z1S					
4	pH value	pH	3.2	3.3	3.1	3.25	3.2	2.5	3.4	2.5	3.1	3.4					
5	Basicity	mval/dm³	0.0	—	—	—	—	—	—	—	—	—					
6	Total Hardness	grades	12.8	12.8	40.8	13.6	13.6	8.8	15.0	10.0	29.6	9.6					
7	Non carbonate hardness	grades	12.8	12.8	40.8	—	13.6	8.8	15.0	10.0	29.6						
8	Carbonate hardness	grades	0.0	0.0	0.0	—	—	—	—	—	—	—					
9	Total iron Zelazo ogólne	mg/dm³ Fe	14.0	7.7	7.15	7.3	5.25	8.95	11.50	8.00	7.10	0.010					
10	Manganese	mg/dm³ Mn	7.0	0.7	0.65	1.15	0.65	0.67	0.75	0.63	0.70	0.65					
11	Chlorides	mg/dm³ Cl	0.0	7.0	18.0	12.0	3.0	15.0	4.0	11.0	10.0	15.0					
12	Ammonia	mg/dm³ N	0.4	0.33	0.18	0.45	0.84	0.56	0.50	0.48	0.48	0.09					
13	Nitrites	mg/dm³ N	0.08	0.01	0.013	0.045	0.015	0.010	0.017	0.009	0.008	0.015					
14	Nitrates	mg/dm³ N	—	0.09	0.09	0.10	0.11	0.17	0.28	0.17	0.11	0.12					
15	Permanganate value	mg/dm³ O_2	2.1	—	7.6	6.0	1.8	45.2	0.6	0.3	0.4	2.0					
16	Mineral acidity	mval/dm³	—	—	1.5	1.76	0.98	1.17	1.20	2.0	0.99	1.10					
17	Total acidity	mval/dm³	—	2.0	4.50	4.42	5.23	5.30	5.15	5.1	4.42	4.60					
18	Phospates	mg/dm³ PO_4	—	0.032	0.018	0.016	0.032	0.016	0.000	0.004	0.004	0.018					
19	Total dissolved solids	mg/dm³	504	572	536	585	590	698.0	821.0	852	1491	634					
20	Mineral dissolved solids	mg/dm³	332	314	386	442	370	391.0	404.0	492	1264	330					
21	Substances dissolved volatile	mg/dm³	172	258	150	143	220	308.0	217.0	160	127	304					
22	Sulphates	mg/dm³ SO_4	295	202	160	332	476	408.0	380.0	298	1250	395					
23	Calcium	mg/dm³ Ca	48.4	13.0	15.0	32.5	14.5	14.5	15.0	15.7	20.5	17.5					
24	Magnesium	mg/dm³ Mg	25.7	7.5	120	8.25	7.5	4.5	7.8	9.8	6.3	20.0					
25	Sodium (photometr)	mg/dm³ Na	6.0	3.7	6	2.0	6.8	7.2	6.3	1.0	1.0	8.0					
26	Potassium (photometr)	mg/dm³ K	4.7	4.7	6	5.5	3.95	7.6	4.2	4.7	4.0	4.8					
27	Aluminium	mg/dm³ Al	—	—	31.2	32.5	—	34.7	30.5	35.0	31.5	28.5					

Specification of water analyses

Object **Lignite Mine „ Przyjaźń Narodów"**

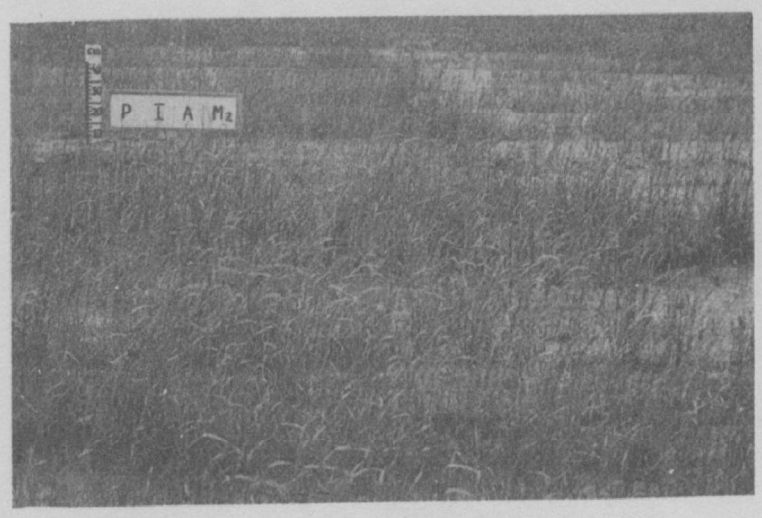
Nr of stand and place of taking **2- Waters from spec made drains on the plot nr 64/comp IV**

	Definition	Unit	Date of sampling														
			25.03	4.04	14.05	3.11	17.05	28.07									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Turbidity	mg/dm³ SiO_2	5	--	—	—	—	—									
2	Colour	mg/dm³ Pt	30	—	40	50	20	30									
3	Smell		Z2R	Z1S	Z1S	Z1S	Z1S	Z2S									
4	pH value	pH	2.8	3.2	3.0	3.4	3.9	4.0									
5	Basicity	mval/dm³	0.0	—	—	—	—	—									
6	Total Hardness	grad as	134.8	4.90	964.0	23.2	47.0	21.6									
7	Non carbonate hardness	grades	134.8	4.90	964.0	23.2	47.0										
8	Carbonate hardness	grades	0.0	0.0	0.0	—	—	—									
9	Total iron Zelazo ogólne	mg/dm³ Fe	115.0	56.0	30.0	9.25	0.86	0.020									
10	Manganese	mg/dm³ Mn	3.8	5.2	5.00	2.05	2.60	1.45									
11	Chlorides	mg/dm³ Cl	0.0	3.5	13.3	3.0	8.0	5.0									
12	Ammonia	mg/dm³ N	0.8	0.03	0.015	0.05	0.10	1.79									
13	Nitrites	mg/dm³ N	—	0.045	0.019	0.022	—	0.017									
14	Nitrates	mg/dm³ N	—	1.75	2.90	0.900	0.78	0.11									
15	Permanganate value	mg/dm³ O_2	13.0	—	8.8	3.1	—	10.0									
16	Mineral acidity	mval/dm³	1.51	—	72.0	0.88	0.76	0.6									
17	Total acidity	mval/dm³	—	—	100.0	20.4	14.6	3.1									
18	Phospates	mg/dm³ PO_4	—	0.01	0.028	0.013	0.005	0.046									
19	Total dissolved solids	mg/dm³	23816	1814.8	9954	2394	21.04	692									
20	Mineral dissolved solids	mg/dm³	20048	11678	7504	1554	15.04	488									
21	Substances dissolved volatile	mg/dm³	3268	6470	2450	840	600	204									
22	Sulphates	mg/dm³ SO_4	11595	9800	4700	252	552	447.0									
23	Calcium	mg/dm³ Ca	286.0	6.5	150	50.0	44.0	70.0									
24	Magnesium	mg/dm³ Mg	55.0	25.0	12.5	36.25	91.2	21.25									
25	Sodium (photometr)	mg/dm³ Na	10.0	11.6	9.0	18.3	6.1	4.0									
26	Potassium (photometr)	mg/dm³ K	11.7	25.0	10.0	12.6	8.7	5.0									
27	Aluminium	mg/dm³ Al	3985.3	—	950.0	—	100.0	5.0									

7.6.4. Photographic documentation.

General view of a levelled out internal stack before the tests commencement.

View of vegetation growing in 1974 on experimental plots - block I and tested combinations of neutralization and fertilization - photos on the pages 144-148.




P I B M1


P I B M2


P I B M3


P I C M1

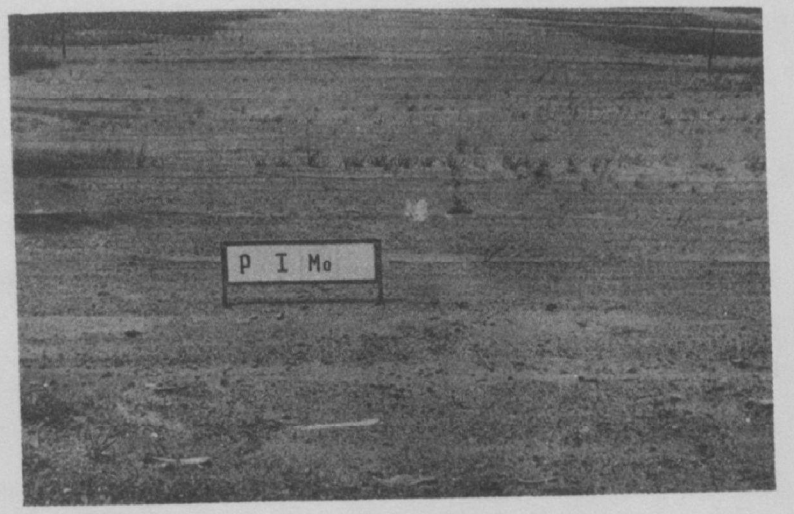

P I C M2


P I C M3


P I D M1


P I D M2


P I D M3


p I Mo

7.7. Summing up of results of the 3 years of research.

The main objective of research carried out in a framework of the project was an elaboration of a complex technology of technical and biological reclamation of the toxic spoil stacks of surface mines of lignite. The program of the research took into consideration the following detailed problems:

1) Methodology elaboration of the toxicity level evaluation of the overburden and the spoil stacks formations.

2) Elaboration of the neutralization methods of toxic soils on the spoil stacks in adaptation to agricultural or forestry restoration.

3) Elaboration of the neutralization technology of toxic soils on very steep slopes, and the principles of their biological consolidation preventing the erosion.

4) Selection of a qualitative and a quantitative composition of vegetation initiating the soil creating processes, and actively contributing to a biological neutralization of toxic formations.

5) Determination of an appropriate agrotechnique of the reclamation work.

6) Elaboration of guide - lines the overburden management, having for its object the liquidation or limitation of toxicity, through the proper distribution of formations with such properties.

The 3 years period of carried out experiments, as for the nature investigations, was relatively short, and it would be very beneficial to continue the observations during next few years.

7.7.1. The management with overburden.

The lands occupied by the surface mining are being transformed in various ways. The principal their portion (82 - 87 %) undergoes a substantial transformation in the course of direct excavation operations - the displacement of ground masses. The remaining portion constituting about 13 - 18 % of the general taken

over terrains, is being transformed to a small extent. On these terrains namely there are being constructed accompanying objects: industrial, transportation, administrative - dwelling, social, recreational ones etc. the conditioning and associated with an economic activation of the area.

In order to determine the adequate solutions providing a high quality of formations dumped on the surface of spoil stacks necessary is a very accurate qualitative and quantitative reconnaissance of the overburden. Only on the basis of such a reconnaissance is possible to determine the best technology for the excavation operations taking into consideration the requirements of reclamation.

In the polish lignite surface mines the overburden constitute several types of soil of different physical mechanical and chemical properties - silts, clays, tertiary and quaternary sand occurring often not regularly.

With the not orderly mass removal of the overburden appears on the terrains of stacking a mosaic of formations of various origins and compositions. A transformation of these formations into soils of appropriate suitability with biological methods was very difficult, and in many cases outright impossible - especially on the terrains of mines on which in the overburden there occur toxic formations. Professor T. Skawina elaborated for practical purposes a five degree classification of the overburden formations regarding their suitability for the economic restoration.

A - soils very good, suitable for the agriculture restoration,

B - good soils, less suitable for agricultural restoration, but very amenable to a forestry recultivation,

C - faulty soils, not suitable for agricultural restoration, but suitable for silvicultural utilization, only after some partial improvement effected on them,

D - bad soils sterile not suitable for economic restoration,

E - toxic soils.

The soils of the A, B, C classes are generally characterized as the so called potentially productive soils.

The inclusion of the soils into one of the classes is based on laboratory tests and in active, working mines also on the field tests. Dependent on the amounts of soils of particular classes and the planned directions of economic restoration, a technological model is determined of the overburden removal and of its stacking. Three types of models are being considered.

I. Model based on a large scale mass removal of overburden.

This model is used when the method of overburden removal and its stacking has no influence on the assigned direction of the recultivation. This obtains in two cases:

I. 1. When the overburden consists wholly of potentially productive soils (A, B, C). A dominating significance in these instances have the biological methods, transforming the soils.

I. 2. When the overburden is made wholly of soils, that have no ability to reproduce the live matter (D, E).

Of significance in these cases is the fertilization and neutralization performed in the course of detailed recultivation.
This model is typical for a forest recultivation determination.

II. Model based on a controlled management with the worst soils of of overburden.

This model is being applied, when in overburden appear relatively little of the D and E class soils, and when the degree of their noxiousness is considerable.
In order to restrict their negative influence on the effects of reclamation and recultivation two versions are used.

II. 1. Location in the spoil stacks' deeper layers of worst soils of overburden and the insulation of their effects by a thick layer formed from potentially productive soils.

II. 2. Deconcentration of the negative effects of toxic or sterile soils' occurrence, by way of their dispersion in a mass of potentially productive soils.

III. Model based on a controlled management with the best soils of overburden.

This is a typical model for agricultural recultivation assignment, as its basic assumption is the attainment of soils of a high production capability, providing the possibility of applied recultivation immediately after the completion of basic reclamation or after few only executed initiating treatments in the phase of detailed reclamation. The models based on a principle of a controlled management of overburden - in surface mining employing the belt conveyeor transportation - should satisfy few fundamental requirements, the most important of which are:

- the provision in the excavator - belt conveyor - stacker technological systems of a possibility to direct the winning fed from selected excavators to selected stackers,
- the provision of variations in the effected redirecting the overburden material from particular excavators to particular selected stackers, without halting the excavator - belt conveyor - stacker system or even for a momentary stopping, such that would have a bearing on the efficiency of the whole system,
- effectuation of division of the overburden into working levels and the spoil stack's into the stacking levels, taking into consideration the soils' quality and the closely connected with it reclamation requirements,
- adequate training of the staff to perform direct excavation, preparing it for the tasks within this sphere, making the people sensitive to the environment protection problems.

All the considered above models were being used on a majority of mines during the period of their development. In the initial period i.e. during the period of gaining access to the lignite, the I - model was used working on a large scale mass removal of overburden. In a later period but still during the stacking of the being removed overburden on an external spoil stack the II - model was used - during the period of the controlling selective management

with worst soils; - and after going over to the internal stacking the III - model was used for the controlled management with the best soils of overburden. The model based on a selective removal of the top soil (the most accurate removal) is not being used on a practical scale in Polish circumstances. The performed technical - ecnomic analyses show the non - profitability of this kind of approach mainly for two things:

- the very low quality of soils occurring on the being worked terrains - mainly of the IV and V class and very rarely only of III - rd class, with a very small thickness of the top-soil,
- considerable distances for the soil transportation from the foreground of the advancing opencast excavation to the spoil stack site - with the added to it great depths of the mines.

The III class soils are being utilized most frequently for the improvement of soil quality on the adjacent to the mine terrains and as material required to consolidate the trench sides and the transport system embankments, the permanent and important components of a surface mine, such as the belt conveyor ramps, machines ramps etc. i.e. where the biological consolidation is used only for the protection of these objects against a washout by rainwaters.

7.7.2. The shaping of worked out terrains.

In the surface mines, in the course of their exploitation, three main forms of the terrains are coming into being, differing chiefly in the respect of the relief formation and the water conditions prevailing within the reach of these forms. Their proportions depend mainly on the depth of the deposit occurrence. These forms are as follows:

- The external spoil stack - considerably uplifted over the surrounding it natural terrain.
- The internal spoil stack - formed flush with, or slightly raised above the surrounding it terrains.
- The final excavations - terrains depressed in relation to the adjacent terrains, with the greatest depth being equal to the depth of the mine.

The stability of slopes and the requirements of reclamation as derived from the planned direction of these terrains recultivation determine the final geometrical configuration of particular forms of the worked out terrains. The reclamation requirements in relation to the whole system of slopes do not call for a more gentle incline, than the derived one from a geotechnical surveying. However, in relation to particular slopes in a system of slopes where a requirement arises from the reclamation demands' point of view for a gentler incline, motivated by the need for performance of many meliorating and cultivating treatments, in the process of the slopes' reclamation and recultivation. Regarding the formation of the flat top portions of the external and internal spoil stacks, these are being determined by the technical conditions, such as are derived from the anticipated economic assignment of these terrains after their industrial exploitation accomplished.

The configuration of the worked out terrains is at the same time one of the more important factors deciding the recultivation assignment. For the external spoil stacks and for portions of the internal spoil stacks when these are appreciably raised above the surrounding land the adoption of forestial restoration is being contemplated as a rule. The direction of agricultural restoration is practiced only on internal spoil stacks. The direction of aquatic recultivation is being practiced on final excavations or on parts of the excavation specially for this purpose predetermined and not covered up to the level of the surrounding terrain.

Occasionally a communal direction of economic use is resorted to such as for example the airfields for planes of the industrial or medical service, and also small areas are reserved for communal or industrial developments. The essential configuration of the terrains is executed by the basic working and stacking machines, and based on instructions of reclamation regarding the final shape is being achieved by means of auxiliary machinery - most often by bulldozers. The basic machines owing to their size have only limited possibilities of an accurate formation of slopes and levels.

Working these machines with a maximum efficiency and reach additionally restricts these possibilities. So far as the work of stackers

is concerned, then with a maximum care contributed by their operators to an accurate formation of the erected external permanent spoil stacks, one is in a position to achieve an approximate shape as shown on fig. 10.

The execution of a final adopted configuration of the spoil stack is regarded as a part of reclamation work itself. On the top portion surfaces of the spoil stacks a levelling of the terrain is made so as to achieve surfaces of varying gradients. The directions and the gradients of these inclines are chosen in such a way, that is possible to carry away waters gravitationally from the top area by means of draining ditches, especially constructed for this purpose, i.e. taking water down the slopes. In polish climatic conditions in constructing the spoil stacks from formations with prevalence of cohesive soils, the surplusses of water occur periodically. The requirement to fast offtake the water excess is dictated by agrotechnical considerations and by the requirement of slopes stability. Heavy soils belong to the soils, with a relatively easy cultivation, but only by a determined humidity level, which as rule lasts only a very short time. During the period of excessive humidity the machines sink in a quag, and in a dry weather the cultivation treatments encounter too much resistance and large solid masses and lumps are in evidence.

On the basis of practical experiments realized until now, the inclines not greater than 5 % are used on the tops of newly formed spoil stacks, and on very small areas of the spoil stacks the 10 % gradients are observed. By larger gradients an erosion occurs. The shaping of spoil stack slopes and of final excavations absorbs most of the attention and effort as these are maximally exposed to erosion - mainly to water erosion. A very disadvantageous consequence of waters flowing down the slopes of permanent external spoil stacks is the drifting of washed out material from the stack onto the adjacent terrains. The suppression of erosion is therefore an important issue, both for the reclamation and for the protection of adjacent terrains.

The carried out tests of erosion suppression on steep slopes by way of biological consolidation introduced in a form of trees, shrubs and grasses gave negative results. Only the intensity of occurrence decreased. Adequate, satisfactory results were achieved only after an occa-

sioned decrease in the gradients of slopes.
Now the following way of slopes formation is being practiced: (fig. 11).

- the incline of the entire system of slopes - should be in accordance with geotechnical calculations,
- the incline of particular slopes should not be greater than the 1 : 3 ratio,
- the slopes higher than 10 m are divided additionally by intermediate shelves formed on them, of a 5 - 7 m width, inclined in its gradient to the inside.
  The vertical distance between shelves is 8 - 10 m and in the zones of greater atmospheric precipitations it comes down to even 6 m,
- the formation on the spoil stack's top portion surface of counterslopes made by the verges of the slopes. Such an anti - slope is inclined to inside with the gradient of 5 %.

The counterslopes formed on the top flat portions of the stacks protect perfectly well the slope system against a washing out by erosion induced by the rainwater flowing down the slopes. The creation of counterslopes (antislopes) is the more important, the higher are stacks and the more impermeable the soil, forming these spoil stacks. The banks (walls) of final excavations, positioned above a stable water table level are being formed in accordance with the presented above rules. The banks situated below the water table's stable level are formed with only basic excavators, to a general incline as the one determined by geotechnical surveys, with the consideration of changed water conditions relevant to the phase of the exploitation operations performed. Also the requirements derived from the planned economic use of the water reservoir is being taken into consideration, where the formation of the final working is concerned. Part of the reservoir is being formed in such a way, as to acquire, after the reservoir is filled, areas with small depths, to be utilized as beaches, for angling, etc., and to provide proper conditions for a natural fish breeding.

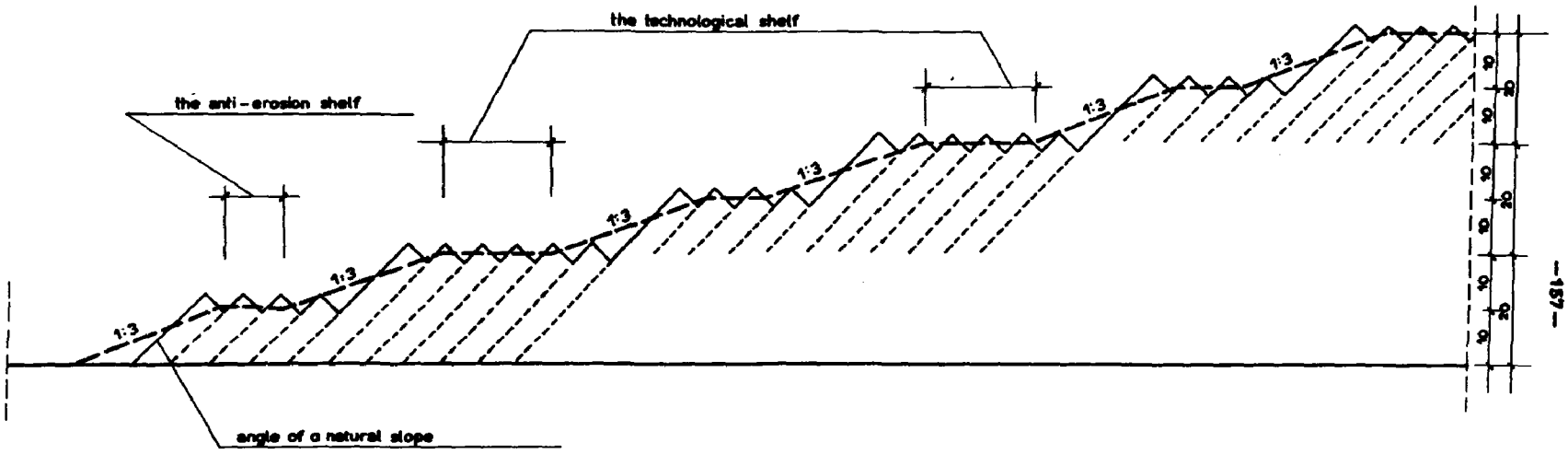


Fig.10 Scheme of the spoil stock formation by a stacker machine

PAGE NOT

AVAILABLE

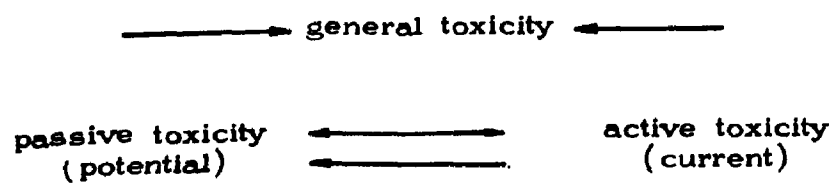
DIGITALLY

7.7.3. Evaluation of the toxicity degree in the overburden and spoils formations.

Toxicity of the overburden and spoil stacks' of the surface mines results mostly from the presence of:

1) sulphides, native sulphur, or sulphites
2) salinity
3) greater amounts of trace elements (for example B, Pb, Zn, Cu, As, P)
4) easily hydrolysing Al salts
5) radioactive elements.

Evaluation and nature of the toxic reacting of the soil medium on the introduced vegetation in the course of reclamation are difficult even when three is only one cause of toxicity, as for instance the sulphides on the spoils of surface mines of lignite. The mechanism of phytotoxic compounds' transformations and forms of their manifestation in the course of weathering are complex and still not accurately known. The research on toxicity of the worked out terrains indicates, that there should be distinguished at least two forms of toxicity interlinked:



Passive toxicity (potential) in the overburden and on the spoil stacks of lignite surface mines is connected with the presence in the soils of the not yet decomposed sulphides. Not without a significance is their form of occurrence (mineral composition) and the way of their distribution in soils of different lithological set up. The mentioned factors affect the rate of weathering and further the possibility of appearance of an active toxicity.

Active toxicity (current) is connected first of all with a raised content - in a liquid or gaseous phase of the soil medium - of compounds having harmful character for the biological processes. These compounds can also occur in a solid phase, but in a form readily passable in the solution. In the case of overburden and of spoil stacks of the lignite surface mines, the cause of active toxicity is sulphuric acid and other products of a biological and chemical decomposition of sulphides, and also compounds originating as a result of influence of these products of decomposition onto the mineral and organic material of the soil medium.

A typical symptom of active toxicity is the excessive soil acidification, hence the (pH) reaction is being generally recognized as the basic criterium of toxicity. The chemical diagnostics of toxicity is sometimes being widened through the employed supplementary criteria, based on the content of replaceable aluminium (Al_r) and hydrolytic acidity (H_h). The content of this acidity is very often being assumed as a quantitative criterium for the calculation of lime amount (CaO), required for the reaction controlling.

The results of carried out investigations indicate that the acceptance of reaction as a basic criterium for the toxicity level evaluation is accepted within a limited scope, and namely in reference to soils characterized by the occurrence of active toxicity only. Partly satisfy such conditions the soils of spoil stack of the lignite surface mine "Przyjaźń Narodów" of which soils are very strongly acidified (pH in KCl 3,0), and in which no sulphides occur but solely the products of their decomposition.

The basing of a diagnosis on a determination of toxicity level of soils, whose reaction amounts to 3,0 - 4,0 pH in KCl or even when is higher than that, can be deceptive, primarily when:

1) The object of a diagnosis are soils characterized with a significant potential toxicity, and when the mechanism blocking it is weak.
2) When the harmfulness of phyto-toxic compounds is mitigated or intensified by some factors connected with the composition or the properties of soil. To such factors belong the mineral and granular composition, the presence of organic substance, the resources of nutritious components for the plants, the water - air conditions etc.

The named matters are conducive to a detailed examination of possibilities of basing the toxicity level classification on results of denotations of the base - forming compounds content, mainly the Ca and Mg, and the acid - forming compounds, chiefly the sulphur. The up to now used method of evaluation of the toxicity level, based on a so called balance of bases and acids, was elaborated in the East Germany by Mr. K. Illner. This method allows to describe the general and the potential toxicity, but it does not take into consideration the mentioned earlier softening up factors, or the factors intensifying the harmful effects of toxic compounds. This fact limits the practical adaptability of this method, as have proved our investigations carried out in the framework of this project.
In the case of soils of the Lignite Surface Mines "Turów" and "Przyjaźń Narodów" plots, values of the bases and acids balance were similar, and yet the real differences in the toxicity level were very great. This points to the necessity to increase the elements quantity, on which is based the appreciation of a toxicity level. It shall involve the requirements of further pedological, chemical and especially biological research continuation regarding the mechanizm of toxicity manifestation and of the factors stipulating its neutralization.

7.7.4. The methods of neutralization of toxic soils on the spoil stacks in their adjustment for an agricultural or silvicultural restoration.

On the experimental plots of the Lignite Surface Mines "Turów" and "Przyjaźń Narodów" there were tried in the years 1973 - 1975 the following 4 neutralizers, applied in various doses, independently or in several combinations, used in one or two layers:

1) the agricultural ground quicklime - CaO
2) the ground phosphate rock of a 40 % $CaCO_3$ content and 30 % of P_2O_5 content
3) ammonia water 25 %
4) magnesium - oxide (magnesia) lime (CaO, MgO) containing about 40 % of CaO and 20 % of MgO.

The inspection tests of the course of neutralization process, observations of the growth and health of the vegetation, its flora composition and amounts of yields allow to draw the following conclusions:

1. Among the tested out methods of liquidation of excessive soils' acidification the best results gave the simultaneous employment of two neutralizers, and namely:

   a) on the spoil stacks of the Lignite Surface Mine "Turów" the application of agricultural, fertilizing, ground quicklime, CaO, together with the ground phosphate rock,

   b) on the spoil stacks of the lignite surface mine "Przyjaźń Narodów" the employment of magnesia (megnesium oxide) lime, CaO, MgO, jointly with the ground phosphate rock.

   The phosphorus neutralizer performs a very important function, blocking the harmful for the development of plants, readily hydrolyzing compounds of aluminium and iron, and apart from that it is a fertilizer too. It became evident in connection with this, that due to the placing of CaO lime and ground phosphate rock, at different depths in the soil, both these neutralizers can be used simultaneously. The lime in such a placement does not hinder the plants from deriving the phosphorus from the ground phosphate rock.

2. The doses of neutralizer should be adapted to the planned line of reclamation. Linked with this are defined requirements concerning the value, which the reaction (pH) has to achieve, on various depths of the soil profile, and the time length needed for the attainment of this state. The results acquired in the course of three years of research work show, that for the soils toxically acid there exists a certain threshold value of the reaction, the stepping over which even in small way not only makes possible the development of vegetation but also allows to achieve even sizeable crops. This threshold value in the conditions of the investigated mines is contained probably within the sector of 3,0 - 3,5 pH in KCl. It is different for different soils, as it depends on many factors such as the form of toxicity, the mineral and lithological soil composition, presence of organic substance etc. The doses of lime necessary to negotiate

the threshold value of the soils acidification amounted in the lignite surface mine "Przyjaźń Narodów" to 25 - 50 t/ha of CaO, MgO and in "Turów" to 5-10 t/ha of CaO.

3. In the case of agricultural reclamation the doses of neutralizers are not required to secure outright the rise in reaction to an optimum value needed for the development of the crop plants, i.e. of a reaction which would be contained within the 6,5 - - 7,5 pH limits, as there is such a tendency where the agricultural soils are being limed. Since the acid reaction of the reclaimed soils has a chemical character, as the case with ordinary soils usually is, and not always is connected with it, the whole lot of unfavourable features, such as the improverishment in the Ca, Mg and other nutritious components, also the decomposition of silty materials, and the acid character of the humus. For this reason in the soils being reclaimed evem a small rise in the reaction value to more than the threshold value, facilitates an almost normal development of vegetation, despite the fact that the reaction in reality is still very acid. This permits a stage by stage liquidation of an excessive acidification, where at the first stage there the free H_2SO_4 should be eliminated, and blocked the potential acidity, and the reaction in the 0-30 cm layer should be raised to the 4,5 - 5,0 pH value. In the second stage the neutralized layer should be made deeper, through an additional liming employed jointly with a special cultivation effected (deep plowing to 0,5 - 0,6 m). Further propagating of neutralization should be made by way of biochemical processes.
On account of the water deficiency and the necessity of roots' penetration into the deeper layers of subsoil, the depth of neutralization during the first stage should be greater on the sandy soils than on the clayish soils. Hence also in case of sandy soils one prefers the neutralization executed in two layers.

4. With the forestral reclamation of soils on the spoil stacks of the "Turów" lignite surface mine, there achieved were positive results, with an application of a single layer neutralization connected with an introduction of herbal vegetation striking roots deep, and this fact facilitated the displacement of the neutralizer deep down into

the ground. However in the course of forestrial reclamation of soils on the stacks of the "Przyjaźń Narodów" surface mine and presumably of all other similar soils, there was the necessity to execute the neutralization in two layers' placement. If this should be impossible because of technical considerations, then the neutralization in one layer should go along with the cultivation of a herbaceous vegetation developing roots very deeply and this should be maintained longer the worse are the water - air conditions on the spoil stack.

7.7.5. The technology of toxic soils' neutralization on very steep slopes and the rules of their biological consolidation preventing the erosion.

An elucidation of issues connected with the biological consolidation which on toxic slopes must be preceded by the soils' neutralization, requires longer period of research work. The results obtained in the course of experiments carried out on the spoil stack of the Turów lignite surface mine allow only an initial formulation of conclusions, which had been collated with observations carried out on the slopes of this spoil stack, reclaimed in the years 1960 - 1972. Summing up the achieved results of research one can state the following rules of the technology for the anti - erosion biological consolidation of the steep toxic slopes.

1. The to be applied on the slopes neutralizer should be very active, and be in a concentrated form. From the generally used neutralizers, the agricultural ground, fertilizing quicklime (CaO), of a possibly high quality, or the magnesia (magnesium oxide) lime (the CaO, MgO), could be recommended.
2. The doses of neutralizer should quickly provide the exceeding the reaction threshold value (pH), and to at least such a depth, to which plants will be introduced. More correct though would be the application of higher doses, which would provide:

a) in the first phase, raising the reaction of the top layers clearly to beyond the reaction threshold value,

b) making good the inevitable losses caused by erosion,

c) in the further phases the liquidation or the reduction in the acidification of deeper layers, mainly through the migration of the neutralizers together with the infiltrating waters.

These doses on the soils of the spoil stack of "Turów" lignite surface mine amount to about 10 t/ha of CaO, or to an equivalent amount of other neutralizer, and on the soils of the "Przyjaźń Narodów" stack - the 40-50 t/ha of CaO are required.

3. The method of the neutralizer's introduction should be such as to provide possibly the fastest reaction with the soil and also to limit the losses of neutralizer caused by wind and water erosion. Such effects can be achieved through a mechanical loosening of the slope's surface and the digging of pits for the plants, still before the application of the neutralizer, even then when neutralization considerably is in time ahead of the planting of the tree and shrub vegetation.

4. The fertilization employed by a biological consolidation of slopes involves the NPK fertilizers, with the provision, that one should use their active, quickly producing effects forms. As the possibilities of agrotechnical treatments on the slopes are limited, therefore in order to reduce the losses of fertilizer one should sow it on previously loosened surface. The improved possibility of the fertilizer utilization can be achieved when adopting the following plan of fertilization:

a) the initial NPK fertilization, to stimulate the acclimatization of the vegetation,

b) nitrogenous fertilization, provided outside the roots, used in few doses' amounts dependent on needs.

5. The halting of erosion on the steep slopes is possible through the introduction of herbaceous vegetation in a shape of papilionaceous plants mixture with grasses. The species coming into the composition of these mixtures should satisfy the following requirements:

a) fast germination and growth,

b) resistance to drought and to sudden chemical changes of the medium, which are rather frequent, especially during the first period of neutralization,

c) robust root system

d) small height.

The grasses create the protective cover quickest. In a mixture though they must be accompanied by the papilionaceous plants on account of their nitrogen bonding ability, the fulfilling of soil producing function (deeper root system) and a nursing role performed in regard of the seedlings of trees and bushes.

6. The experiments have shown, that when employing the mixture of a composition given on table 4, one can quickly stop the erosion. The participation in it of Phleum pratense should be somewhat smaller owing to its strong competition in relation with the cuttings. At the expense of this species one should increase the quantities of the remaining species, amongst others of the Lupinus polyphyllus, Lotus corniculatus and Trifolium repens. One should also, and this requires a verification still, consider in the mixture composition the yearling grasses, for example the Lolium multiflorum westerwoldicum.

7. The arborescent species introduced on the slopes can be divided in respect of their performed functions into:

a) the phytomeliorating - among others the Alnus glutinosa, Salix caprea,

b) the protecting - amongst others the Robinia pseudacacia, Hippophaë rhamnoides, Caragana arborescens,

c) the biocenoseous - amongst others the Sorbus aucuparia, Rhus typhina, Sambucus racemosa, Sambucus nigra, Evonymus europaea,

d) of a target destination - amongst others the Larix europaea, the Quercus borealis, the quercus robur, the Populus robusta, the Populus Hybrida - 275, the Populus serotica, the Fraxinus

excelsior, the Acer platanoides, Acer pseudoplatanus, Carpinus betulus, Fagus silvatica.

On the very steep slopes the proportion of seedlings from the group of the phytomeliorating and the protective species should reach the 65 - 80 % level, whereby among the protecting species, for the conditions suiting the spoil stacks of the "Turów" mine as the most suitable one has shown itself to be the Caragana arborescens, and from the phytomeliorating the Alnus glutinosa.
Used for the planting should be material of a high quality, from a nursery acquired. The spacing of the plantings should be sufficiently dense, no more though than 1,5 x 1,5 m. Very favourable from the economic, and other points of view, are plantings of shoot cuttings, which can be set up in more humid places, with more dense spacing out, but of no more than 0,5 x 1,0 m distances.

7.7.6. The selection of a qualitative and a quantitative composition of vegetation initiating the soil producing processes, and actively contributing to the biological neutralization of the toxic formations.

The vegetation initiating the soil producing processes and activating the neutralization of toxic compounds contained in soils of the spoil stacks should be satisfying a number of requirements. To the most important ones belong the:

1) Particular resistance to acidification and to its' effects and to the dynamics of the reaction changes and also to other chemical peculiarities in a vertical and horizontal cross - section of the root zone.

2) Very good resistance to particularly bad water - air conditions, the typical characteristic of which are the extremely short periods of a favourable soil humidity. Long lasting especially are the dry weather periods, which worsen even more the already adverse chemistry of the soil medium.

3) The very fast growth providing a coverage of the surface and curbing all forms of erosion.

4) Production of a large mass above and below the ground surface, whereby this biomass should particularly readily be subject to the mineralization and especially to the humification.

5) The roots of the plants should penetrate possibly the largest mass of soil, securing thus a deep vertical drainage by means of the thick tap roots.

6) To possess the ability of bonding the free nitrogen from the air and availing of difficult assimilable forms of the phosphorus and other microelements.

It is obvious that only one of the species of plant cannot satisfy all these needs. With difficulty this can satisfy a made of many species mixture, and only then, when the reclamatory operation were to mitigate the bad chemical and physical conditions of the soil medium. A proper shaping and regulation of hydrological conditions, then the neutralization, the mineral fertilization, the cultivation, the nursing and other like agrotechnical operations should serve this objective.

On the top flat portions of the spoil stack of the "Turów" lignite surface mine good results were achieved from the application of a mixture given on the point 7.4.2.3. It appears these results could even be better provided the floristic composition of the mixture were to be selected so as to suit the employed neutralization method. In case of the CaO alone or in a combination with the ground phosphate rock application for neutralization, the participation of the papilionaceous plant, and especially of lupin, should be increased by at least 50 %. On the other hand in application of ammonia water in conjunction with ground phosphate rock as a neutralizer, the lupin seeds should be eliminated from a mixture, increasing instead the proportion of grasses in it by about 100 %.

On the spoil stack of the "Przyjaźń Narodów" lignite mine the good results were achieved when using the mixtures M_1 and M_2, of which the qualitative and quantitative composition is given on the in point 7.6.2.3. One should eliminate from the Mixture M_2 the Melilotus

Albus, introducing in its stead the e.g. *Lotus Corniculatus*.

7.7.7. The determination of a suitable agrotechnique for the reclamation operations.

The cycle of experiments realized on the spoil stacks of "Turów" and "Przyjaźń Narodów" lignite surface mines involved the cultivation of the mixtures of perennial papilionaceous vegetation with grasses. This vegetation constituted a biological test of effectiveness of the used methods of neutralization, and moreover it's task was to initiate the soil producing processes. Subordinated to these superior objectives was the agrotechnique, which was limited to the pre - sowing cultivation, work connected with an intensive mineral NPK fertilization, and in following years it was restricted to a supplementary fertilization outside the roots, connected with the loosening of surface, and the mowing of the mixture, and leaving the comminuted biomass on the being reclaimed surface.

A 3-yearly period of experiments allows also to formulate one's view regarding the advantages and disadvantages of the employed agrotechnique. However taking into consideration the planned for the next years realization of the research program regarding the agricultural reclamation of the spoil stacks, more advantageous will be to propose the rules of a suitable agrotechnique on the being reclaimed terrains, after the lapse of few subsequent vegetation seasons.

8. REFERENCES

Bauman K. and others. — Reclamation of toxic spoil stack for various selected soil conditions - with the Turów Lignite Mine as an Example. 1- st Interim Report Jan. 1, 1973, Oct. 31,1973, 2- nd Interim Report Dec. 1, 1973, Oct. 31,1974.

Birecki M. Kuliman i inni — Untersuchungsmethoten des Bodenstrukturzustandes, Berlin 1968. Investigation methods of the soil structure conditions, Berlin, 1968.

Gogatisvili A.D. — Problema vosstanovlénija pocv posle razrabotki rudnych mestorozdenij otkrytym sposobem. Sbornik naucnych trudov Estonskoj SSR.

Greszta J. Morawski S. — Rekultywacja nieużytków poprzemysłowych, PWRiL Warszawa 1972 Reclamation of post - industrial waste lands, PWR and L.

Heide G. — Kulturböden aus künstlich umgelagerten Bodenmaterial. Proceedings Inst. Congress of Soil Science 1974. Fertile soils obtained through selective stacking.

Illner K. Lorenz W.D. — Das Dormsdorfer Verfahren zur Wiederbarmachung von Kippen und Halden des Braunkohlenbergbaues, Berlin Humbolt- Universität 1965. The Dormsdorfer Procedures for the Restoration of Stacks and Dumps of the Lignite Opencast Mining, Berlin Humbolt University 1965.

Jonas F. — Tvorba pudy na výsypkách složených z sedých micennich jílu v oblasti severoceskeho hnedouhelneho reviru. Lesnictví 18 1972.

Jonas F. — Nadložní jíly a jejich kvalitativní diferenciace pro ucely rekultivace v revíru SHR. Uhlí 6 1972.

Knabe W. — Zur Wiederurbarmachung im Braunkohlenbergbau, Berlin, 1959. Restoration in the Lignite Opencast Mining.

Materiały XIX Ogólnopolskiego Zjazdu Naukowego Polskiego Towarzystwa Gleboznawczego na temat: "Ochrona środowiska glebowego" Katowice - Kraków, Puławy 1972.

Materials of the XIX All. Polish Pedological Society Scientific Congress, entitled "Protection of the soil environment". Katowice - Kraków - Puławy, 1972.

Materiały z III Internationales Symposium über Rekultivierungen der durch den Bergbau beschadigten Böden. Praha, Forschungsinstitut für Melioration 1969.

Subject of the Reclamation of terrains devastated by Opencast Mining. Prague, Research Institute for Melioration 1969.

Materiały z IV Symposium über Wiedernutzbarmachung der durch die Industrie devastierten Territorien. Leipzig 1970 DA der Landwirtschaftswissenschaften zu Berlin.

Materials of the IV Symposium on the Subject of devastated by industry terrains' restoration. Leipzig 1970, German Academy of Agricultural Sciences in Berlin.

Razrabotka sposobov rekultivacii landsafta narusennego pronyslennoj dejatielnostiu. Materiały z V Międunarodnyi simpozium. Selskochozjajstwiennaja Akademija im. G. Dymitrova. Inst. Pocvovedenija i Agrotechniki im. N. Puskarova 1973.

Elaboration of the reclamation methods of the disturbed by industry terrain. Materials of the V International Sympozium Agricultural State Academy, memorial to G. Dymitrov Institute of Agrotechniques, memorial of N. Puskarov, 1973.

Motorina L.W., Owcinnikow W.A. — Promyslennost i rekultivacia zemel, Moskva, 1975.

Nowosielski O. — Metody oznaczania potrzeb nawozowych PWRiL, Wa-wa 1968.
Methods of the fertilizer requir ements determination PWR and L.

Paprzycki E. — Klasyfikacja nieużytków poprzemysłowych, Biuletyn nr 1 Komisji Biologicznego Zagospodarowania nieużytków poprzemysłowych.
Komitet ds. GOP przy Prezydium PAN, Wa-wa 1956.

Classification of post - industrial waste lands. Bulletin no. 1 of the Commission of Biological Recultivation of post - industrial waste lands.
Committee for the GOP by the PAN Presidium Warsaw 1956. Reclamation of soilless terrains.

Patejdl C. — Agricultural Reclamation of Spoil and Areas Disturbed by Industrial Activities.
Vyzkumny Ustav Melioraci, Praha - Zbraslav n. VI t, 1974.

Documentary material presented at the International Special Congress "Mine Spoil Heaps in the Ruhr and their Integration in the Landscape", Essen 1974.

Sindelar B.W., Atkinson R., Majerus M., Proctor K. — Progress report 1973 - 74
Surface Mined Land Reclamation Research at Colstrip, Montana

Sbornik referatov — Rekultivacia promyslennych pustosej. Moskva 1972.

Siuta J. — Rekultywacja gruntów bezglebowych.
Materiały z konferencji naukowo-technicznej nt.: Ochrona gruntów rolnych i rekultywacja obszarów zdewastowanych w północno-wschodnim regionie Polski.
DW Olsztyn 1973.
Materials from technical - scientific conference, entitled: Protection of agricultural terrains and reclamation of devastated areas in north - eastern region of Poland.

Skawina T. — Klasyfikacja terenów pogórniczych dla potrzeb rekultywacji.
Ochrona Terenów Górniczych nr 6 1968.

Classification of mined out terrains for the requirements of reclamation. Protection of the mining industry terrairs nr 6, 1968.

Skawina T. — Możliwości wykorzystania selektywnego zwałowania dla celów rekultywacji.
Górnictwo Odkrywkowe nr 4, 1970.

The possibilities of selective stacking utilization for the reclamation purposes.
Opencast Mining no. 4, 1970 (monthly magazine).

Skawina T.
Trafas M.

Zakres wykorzystania i sposób interpretacji wyników badań geologicznych dla potrzeb regultywacji.
Ochrona Terenów Górniczych nr 16, 1971.

The scope of utilization and the method of interpretion of geological studies' results for the needs of reclamation.
Protection of Mining Terrains no. 16 1971.

Wysocki W.

Odtwarzanie gleb dla rolniczego zagospodarowania zwałowisk na przykładzie Kopalni Węgla Brunatnego "Konin".
Rocz. gleboznawcze 1975, zeszyt 1.

Reproduction of soils for agricultural restoration of spoil stacks with "Konin" lignite surface mine as an example. Pedological year - book 1975, instalment 1.

9. GLOSSARY

Belt conveyor system - assembled in series system of belt conveyors,

Belt conveyor - installation is intended for a continuous transportation of materials,

Bucket wheel excavator - excavator working on a continuous basis by way of a wheel equipped into buckets and transferring the winning with internal belt conveyor onto the transportation arrangements,

Coal band - thin layer of coal, usually of small radius, occurring within the overburden and being removed or intended to be removed together with the overburden material,

Collecting belt conveyor - belt conveyor gathering material from few conveyors; usually a stationary belt conveyor,

Cut (bench) - portion of formation or stack contained between two neighbouring levels,

Ditch - elongated depression executed in a ground and intended for intaking and offtaking water or only offtaking water,

Draining ditch - ditch intaking and offtaking rain waters, or underground and rain waters,

Excavator - a self propelled machine intended for working the soil material on the worked slope in the excation, and loading it on transportation means,

Exploitation front - system of working faces.

External spoil stack - the spoil stack localized outside the open-pit,

Fertilization outside the roots - scattering of mineral fertilizers onto the growing plants,

Front of excavation - exploitation front of open pit working,

Front of stacking - exploitation front of the spoil stack,

Incline of slope (overall angle of slope system) - ratio of altitude (of a cut or a sum of cuts) to the base of cross - section (of slope, or system of slopes).

Initial fertilization - introduction of mineral fertilizers prior to sowing plants.

Intermediate level - level situated between the exploitation levels not equipped with basic machinery,

Movable slope - slope, on which working or stacking is performed,

Internal spoil stack - the spoil stack localized inside the open-pit.

Level - a horizontal area dividing the open pit or stack into cuts,

Neutralization - work connected with the introduction of neutralizer to the soil.

Neutralizers - elements or chemical compounds employed for the purpose of liquidation or limitation of toxic influence of compounds occurring in the soil,

Offtaking ditch - ditch in which water is taken from a drained area of a working or a spoil stack.

Overburden - layers of waste rock occurring over the deposit of coal intended for exploitation,

Overburden material distributing station - assembly of systems. with the aid of which is directed overburden material from the collecting belt conveyor onto the belt conveyor transporting the overburden to a selected stacker,

Permanent slope - slopes on which no working or stacking is performed,

Over stacker layer - stacking above the level on which are standing the stacking appliances,

Pioneering vegetation - vegetation being introduced onto the worked out terrains in a framework of reclamation, with the goal to inhibit the erosion and to initiate the intensification of soil reproducing processes,

Reclamation of worked out terrains - all undertakings and operations connected with introduction of pioneering vegetation onto the worked out terrains,

Recultivation of the exploited-out terrains - all undertakings and operations connected with the introduction of economic activity on reclaimed terrains,

Seam of lignite - continuous layer of lignite occurring between the non-organic soils (rocks) being a subject to exploitation, or intended for exploitation,

Selective stacking - purposeful separate stacking on selected parts of the stack, or on separate stacks of different kinds of spoils according to a determined schedule,

Site of stack - a demarcated terrain intended for the distribution of stacked material,

Shelf - a flat horizontal surface left on the decline between the slopes in order to increase the stability of the slope of a pit or a stack, or executed for the purpose of reduction in water erosion,

Slope - inclined surface formed in the effect of mining operations,

Spoils - soils of waste rock occurring in the overburden and in between the seams of coal,

Stack - spoil disposal (dump, pile, heap etc.),

Stacker - a self - propelled machine intended for continous collection of ground masses from belt conveyors and their disposing onto the front of stacking,

Stacking - the whole of activities connected with the collection and distribution of spoils on a demarcated site,

Stationary belt conveyor - belt conveyor based on permanent concrete foundation,

System of slopes (of stack or working) - side area impounding the open pit working or the stack,

Top portion of stack - the top (crown) area of the internal or external stack almost flat or of a small decline,

Toxic soils - soils, in which are occurring elements or chemical compounds harmful to the growth of plants, or caousing a bad quality of achieved products, from the point of view of their consumption by animals or humans,

Travelling belt conveyor - belt conveyor of a construction adopted to shifting (on skids),

Under stacker layer - stacking below the level on which are standing stacking appliances,

Water down-take - reinforced ditch executed on a slope or system of slopes intended to offtake waters derived from drainage of above positioned condignations of stack or working,

Working - an open pit excavation existing during the time of performed exploitation,

Working face - the length of a worked slope prepared for one excavator or a stacker performing the work,

Working level - level on which the working or stacking takes places together with the haulage,

Printed in Poltegor, 29/76, 50 cop.