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# WATER POLLUTION CONTROL IN POLAND

The paper describes problems that this country has to face in coping with the development of adequate monitoring and control of surface water resources that are estimated to be well below the total projected water demand. The discussion of technical methods of treatment, utilization and reuse of wastewaters is confined to those achievements that have significant technological and economical impact and that warrant international recognition.

## 1. INTRODUCTION

Although well known for its abundant lake districts offering excellent water bound recreation, Poland has in fact one of the shortest supplies of fresh water on the European continent. As compared to the most resourceful countries, such as Iceland, Norway or Switzerland having an average annual outflow of surface waters amounting to 1100–1650 thous. $m^3/km^2$, Poland ranks twenty second in Europe — with an outflow of only 160 thous. $m^3/km^2$, close to that of Roumania, Greece or Spain.

In direct figures, this may mean, in the so-called "dry year", an annual available water volume of some $31.1 \times 10^9$ $m^3$ (fig. 1). Of this outflow some 7.4 billion $m^3$ constitutes the reserve that cannot be removed under any conditions because of biological and sanitary reasons. After substraction, the economically available volume is $23.7 \times 10^9$ $m^3$ which compares unfavourably with the water demand projected for the nineties.

The deficit resulting from almost a 700% increase of this country industrial production in the last two decades, and the unfavourable location of major municipal and industrial agglomerations in respect of the water supplies, create the situation which calls for an immediate and rational water management approach.

Rational management means to provide water resources independent of the season, time and other factors. There are two trends in approaching the problem. One is to decrease water consumption by the use of dry technologies, closed cycles, recovery and water reuse, air cooling, etc.; the other advocates milder effluent standards in favour of increasing

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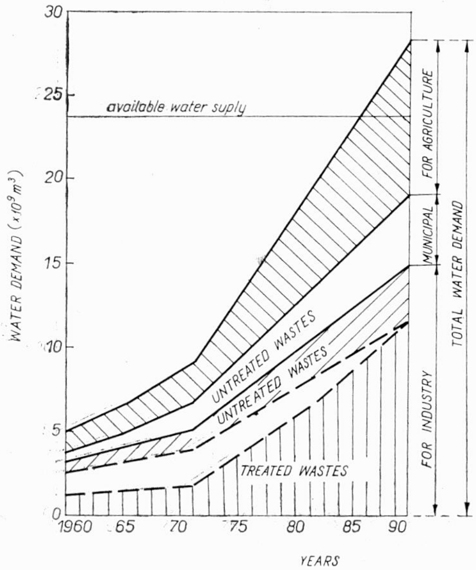


Fig. 1. Water demand against wastewater discharge and water supply in Poland

Rys. 1. Zapotrzebowanie wody i zrzut ścieków oraz zasoby wodne Polski

the available water supply, mainly through retention. The seriousness of the situation has resulted in the fact that in Poland both these trends are realized.

The retention is presently approaching 4% of the annual outflow — far beyond the requirements — and will be increased to 10–12% within the next decade. The real solution seems to lie then in the improvement of water quality of available resources, i. e. surface waters. This is well facilitated by one of the most rigorous Water Quality Acts of 1922, 1962 — The Water Law — revised in 1974 and the centralized administration system. Thus, of the overall 13 billion zloties spent annualy on water resources management, some 30% is alloted to the construction of wastewater treatment plants [1].

The aim of this presentation is to describe the legislative, administrative, technical and scientific activities undertaken to improve the quality of aquatic environment in Poland.

## 2. LEGISLATIVE AND ADMINISTRATIVE MEANS

### 2.1. THE WATER LAW

This country has a long history of strong legislation towards the protection of water quality. The most recent act is the 1974 edition of the revised Water Law [4] — a collection of regulations on the problems of the property and use of water, protection of waters, water and civil engineering, water authorities, etc. The law defines the rules of obtaining water permits any use of surface or ground waters including intakes, discharges, fish farming, retention, etc. The water pollution control section of the Law defines principles and distances applied in zonig water resources against possible sources of pollution and conditions for the discharge of effluents to receivers.

The regulations concerning the detailed concentration of pollutants discharged to surface waters — in general terms such as $BOD_5$, COD ether extract, PCB, and in specific terms such as various metals, pesticides, etc. [2] were re-issued as a supplement to this act.

Classes of surface water quality were established there:

**Class I** includes waters suitable for municipal water supply purposes and salmon fish growth;

**Class II** defines waters that are suitable for growth of fish other than salmonidae and for recreational purposes — including swimming;

**Class III** encompasses waters that are suited only for industrial water supply and for irrigation purposes.

The mean low flow defined as an average from the many years lows (SNQ or MLQ) has been considered as the representative indicative flow to which all the concentrations should be referred. The different classes are characterized by the defined quality parameters — some of them are illustrated in table 1. The same regulation defines permissible concentrations of pollutants discharged to the sewer systems in town. Thus for example, maximum values are set as 700 mg/dm$^3$ for $BOD_5$, for chlorides — 400 mg/dm$^3$, for cyanides below 1.0 mg/dm$^3$, heavy metals usually below 0.1–1.0, etc.

The fines are calculated taking into account the load basis, the length of time of discharge and the category of pollutant (its harmfulness to the aquatic environment).

## 2.2. WATER QUALITY MONITORING AND RIVER CLASSIFICATION

Presently, the territory of Poland is covered by an integrated network of some 1200 conventional monitoring stations and established cross-sections located along approx. 13 000 km of rivers (i. e. streams with drainage area exceeding 300 km$^2$). Manual sampling programmes of these points consist in collecting samples with a minimum frequency of once-in-two-month, up to daily sampling at major points. At seven of the most vital cross-sections along the Odra and Vistula, automatic water quality monitoring stations (AWQMS) are located. The AWQMS have been operating continuously since 1968, either on floating barges or in regular laboratory buildings.

The network, one of the first in Europe organized under the auspices of the World Health Organization and was initially based on imported monitoring equipment. Domestic Aquamer automatic monitors are being installed; capable of accurate measurement and tele-transmission of basic parameters such as dissolved oxygen (DO), temperature, chlorides, conductivity, pH, water level, turbidity, meteorological data, and additional parameters as soon as suitable sensors are developed. The major AWQMS are also used for broad manual bio-assay tests, fish tests, and expanded trace elements analysis.

Table 1

Examples of permissible concentrations of some pollutants in surface freshwaters according to the Polish Water Law

| Parameter | Unit | Water class | | |
|---|---|---|---|---|
| | | I | II | III |
| DO | mg $O_2/dm^3$ | 6 | 5 | 4 |
| $BOD_5$ | mg $O_2/dm^3$ | 4 | 8 | 12 |
| COD | mg $O_2/dm^3$ | 40 | 60 | 100 |
| Saprobic index | | oligo to betamezo | betamezo toalfamezo | — alfamezo |
| Chlorides | mg $Cl/dm^3$ | 250 | 300 | 400 |
| Sulphates | mg $SO_4/dm^3$ | 150 | 250 | 250 |
| Hardness | mval/$dm^3$ | 7 | 11 | 14 |
| Dissolved solids | mg/$dm^3$ | 500 | 1000 | 1200 |
| Suspended solids | mg/$dm^3$ | 20 | 30 | 50 |
| Temperature | °C | 22 | 26 | 26 |
| $N-NH_4$ | mg $NNH_4/dm^3$ | 1.0 | 3.0 | 6.0 |
| $N-NO_3$ | mg $NNO_3/dm^3$ | 1.5 | 7.0 | 15 |
| N— organic | mg Norg/$dm^3$ | 1.0 | 2.0 | 10 |
| Total iron | mg Fe/$dm^3$ | 1.0 | 1.5 | 2.0 |
| Manganese | mg Mn/$dm^3$ | 0.1 | 0.3 | 0.8 |
| Phosphates | mg $PO_4/dm^3$ | 0.2 | 0.5 | 1.0 |
| Cyanides | mg CN/$dm^3$ | 0.01 | 0.02 | 0.05 |
| Phenols | mg/$dm^3$ | 0.005 | 0.02 | 0.05 |
| Lead | mg Pb/$dm^3$ | 0.1 | 0.1 | 0.1 |
| Mercury | mg Hg/$dm^3$ | 0.001 | 0.005 | 0.01 |
| Copper | mg Cu/$dm^3$ | 0.01 | 0.1 | 0.2 |
| Zinc | mg Zn/$dm^3$ | 0.01 | 0.1 | 0.2 |
| Cadmium | mg Cd/$dm^3$ | 0.005 | 0.03 | 0.1 |
| Chromium | mg Cr/$dm^3$ | 0.05 | 0.1 | 0.1 |
| Total heavy metals | mg/$dm^3$ | 1.0 | 1.0 | 1.0 |

The water quality data are analyzed by applying the so-called Polish statistical methods according to which first the correlations between the flow and concentration are found — such as in fig. 2 — and then the so-called indicative concentration (IC) of the parameter corresponding to the mean low flow in the river (MLQ) is established.

Final interpretation consists in plotting the IC values along the river-interpolating or extrapolating the shape of the self-purification curve between the cross-sections — in order to obtain the so-called hydrochemical profile (fig. 3). Comparison of IC of various parameters with the standards for the three classes of water quality yields final classification of the river [13]. In the hypothetical $BOD_5$ profile the values for $BOD_5 = 4.0$ and 8.0 $mgO_2/dm^3$ denote the 20°C upper limits for classes I and II, respectively. The overall classification is done after all parameters have been analyzed.

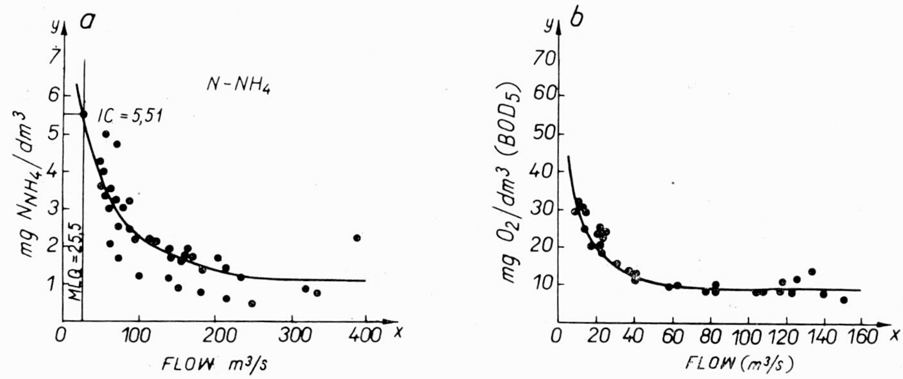


Fig. 2. Example of concentration versus flow relationships: (a) ammonia in Vistula River, (b) $BOD_5$ in Odra River

Rys. 2. Przykład zależności stężenia od przepływu: (a) dla amoniaku w Wiśle, (b) dla $BZT_5$ w Odrze

Based on these results the Water Atlas [5], a compendium of chemical profiles for major rivers in Poland is elaborated every second year. The Atlas permits a design engineer to get immediately information concerning the effluent quality required of his wastewater treatment plant. These data should be completed with the existing and forecasted conditions in a given recipient.

An example of the type of overall changes in the surface water quality is presented in table 2 [14]. It follows from this brief comparison that the overall improvement in the surface water quality, expressed in the decreased global load of pollutants carried by the surface waters, takes place partially at the cost of the decreasing supply of water of the first class quality.

Table 2

Comparison of water quality in major rivers, for years 1967 and 1973, during the food industry full-scale compaign

| Class | Length of rivers (km) | | Change |
|---|---|---|---|
| | 1967 | 1973 | |
| I | 1286.1 | 928,2 | −357.9 |
| II | 1716.4 | 2180.0 | +463.6 |
| III | 1610.7 | 1632.5 | +21.8 |
| beyond stds | 2511.2 | 2383.7 | −127.5 |

The method presented is becoming officially accepted and recommended for the use within the East European countries in solving the problem of both national and international water courses.

## 3. MAJOR APPROACHES TO WATER POLLUTION CONTROL

The problems of the quality and quantity of water in Poland are at present so serious that any novel technology of wastewater treatment is subject to intensive study. Due, however, to the urgency of the situation this country has taken a course on the more economical technologies aimed at upgrading the effluent quality and the aquatic environment. Numerous unique problems that have received research attention resulting in original solutions in Poland include: agricultural and forest utilization of wastewaters from food industry, the methods for in-plant phenol recovery, biological treatment of phenols and sulphite cellulose plant effluents, methods for salinity control from mine drainage, dairy industry waste treatment, in-plant changes in the sugar refineries, hardboard wastes, fiber recovery and biotreatment, plants waste utilization and many others.

Some of this work will be presented in this paper.

### 3.1. LAND DISPOSAL

Irrigation with wastewater is presently far more advanced in Poland than in most other developed countries. The problems that were successfully solved, in rather unfavourable climate for land disposal in this country, include: hygienic-sanitary conditions in-wastes utilization, year-around land disposal, technology for disposal of effluents from food industry, as well as pulp and paper plants and other industries, technical development of disposal techniques and site preparation, agricultural utilization of wastewater, sludges, etc.

The conditions that govern year-around irrigation include calculation of the heat necessary to defrost the soil, selection of a light-permeable soil, the choice of irrigation system and crop types.

Full guarantee of year-around land disposal is provided by the emergency reserve fields which can accommodate wastewaters during difficulties in the main systems. Many years of experience [10, 12] have proved that the reserve fields should have an area of 10% of the working fields system. High doses, up to 3000 mm/year may be applied there, the crops usually being hay or poplar tress. Fig. 4 illustrates the wood mass yield in 7 year and 14 year cycles — working under year-around irrigation programme. The economics of this method of disposal is demonstrated by over 100% increase in the wood yield.

One of the most outstanding achievements is the optimization of the dose — wastewater strength-soil-nutrient requirements system for the campaign industries that operate outside the vegetation period. Out of the 25 mln $m^3$ of wastewaters from the potato industry, almost 70% is utilized fully in agriculture yielding a crop of approx. 80 thousand tons of cereal, or 6 thousand tons of plant proteins [11]. Similar achievements have been claimed for yeast effluents.

Effects of irrigation dose on different crop yields irrigated in the period outside the vegetation season (the potato campaign) are presented in fig. 5.

Other troublesome wastewaters in Poland are disposed on land with significant profit. Many years of field operation proved hay yields of 100q/ha without addition of the mineral

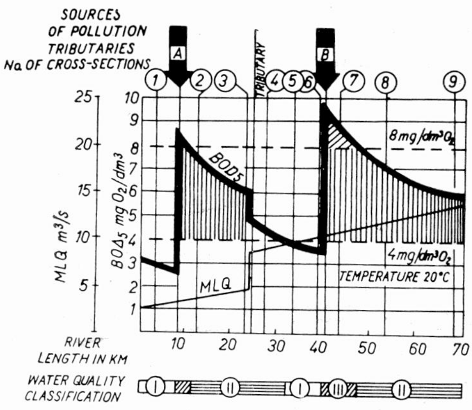


Fig. 3. Water quality classification based on hydrochemical profile of $BOD_5$ — hypothetical example

Rys. 3. Klasyfikacja na podstawie profilu hydrochemicznego $BZT_5$ — przykład metodyczny

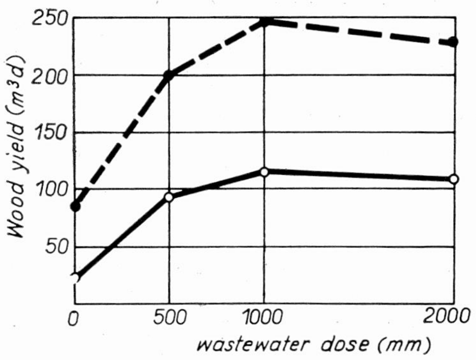


Fig. 4. Poplar wood yield on reserve municipal wastewater irrigation fields:

*1* — 7 years cycle, *2* — 14 year cycle

Rys. 4. Przyrost topoli na rezerwowych polach rolniczego wykorzystania ścieków miejskich:

*1* — cykl siedmioletni, *2* — cykl czternastoletni

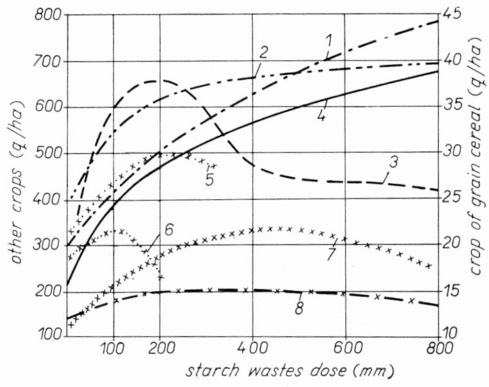


Fig. 5. Influence of irrigation with potato wastewater outside the vegetation period

*1* — corn, *2* — cabbage, *3* — fodder carrot, *4* — fodder beet, *5* — grain corn mix, *6* — oats, *7* — potatoes, *8* — clover

Rys. 5. Wpływ nawodnień ściekami z przemysłu ziemniaczanego po okresie wegetacji

fertilizers. The work proved that the hydraulic loading as high as 6 000 m³/ha did not satisfy the nutrient requirements of the meadows, thus indicating that land disposal is more treatment method than agricultural benefit.

The dairy effluents, highly concentrated, are usually treated in oxidation ditches. Due to the frequently inconsistent performance of the ditches, the land irrigation is applied since it offers excellent finishing treatment and/or agricultural utilization of dairy effluents.

This is illustrated in fig. 6. The figure demonstrates, in full scale operation, the importance of proper wastewater-nutrient balance for optimized crop benefits. Certain industrial effluents, although fully acceptable from the standpoint of public health may require nutrient addition and adjustment of the microelements balance. In this case sugar refinery effluents show a significantly greater nutrient demand than the richer dairy effluents.

### 3.2. NATURAL METHODS OF TERTIARY TREATMENT

Stringent water quality standards in Poland require reduction of the nutrients to a degree seldom attainable in conventional secondary treatment systems. Unfortunately, the present situation calls, first of all, for complete upgrading, and, in certain cases, for a new construction of secondary biological treatment plants. In practice, the tertiary treatment has to be economically justified, usually by such profit as provided by some natural treatment methods.

*Land disposal* practiced in this country means either irrigation for crop or irrigation-soil filtration, used to upgrade the secondary effluent quality or to provide high quality effluent for the primary treated wastewaters.

Examples of excellent removals of nutrients, attained during irrigation of crops with various doses of municipal wastewaters — in full scale — are presented in fig. 7 [10]. The increase of drainage concentration with the increase of the dose is apparent.

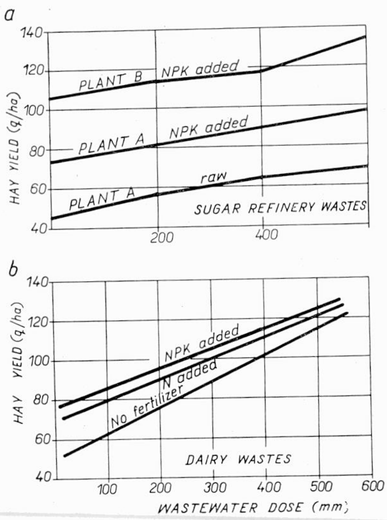


Fig. 6. Agricultural utilization of effluents from the sugar and dairy industries

Rys. 6. Rolnicze wykorzystanie ścieków z przemysłu cukrowniczego i mleczarskiego

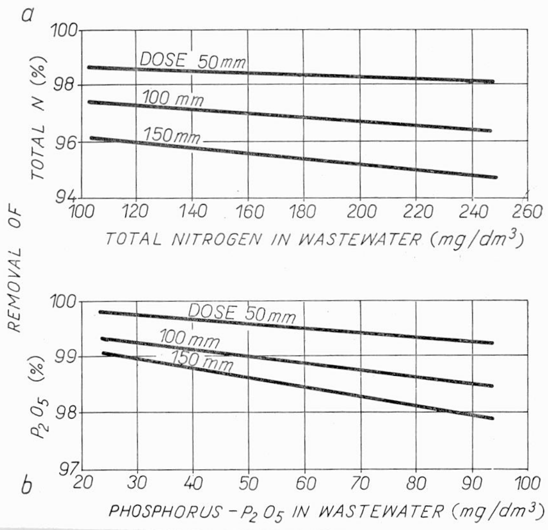


Fig. 7. Nitrogen and phosphorus removal from wastewater at various irrigation rates and increasing waste concentrations

Rys. 7. Usuwanie związków biogennych w zależności od dawki polewowej i stężenia

Aquaculture is another group of full scale tertiary treatment techniques used for years in this country and proven to be technically and economically feasible and profitable. Under Polish climatic conditions however the only aquaculture technique applied so far is the fish farming. Other methods of protein harvesting in tertiary wastewater treatment facilities are still in the development stage due to the solar radiation and temperature problems common to the central Europe countries.

Even though *fish farming* is usually advocated as a tertiary treatment method it has been successfully used for years on the primary effluents. An example is served by the city of Lubliniec which has an overloaded primary treatment plant that discharges the effluent to the fish pond system [15]. The system consists of ponds which can operate both independently and in series. The primary effluent, after mixing with supplemental river water, is introduced to the first pond, i. e. an unstocked stabilization pond. Depending on the flow-through conditions and wastewater concentrations in the ponds, intensive surface aeration may be practiced.

The experience with the fish farming has indicated that the most suitable stock material is carp fry. During recent years stocks of 12 500 fishes (fry) per hectare have been used; the unit weight of fry being 50 g. By autumn the fingerlings of 350 g weight are attained. The seasonal losses do not exceed the 25–30% (i. e. are not excessive) and many times are even smaller. The present output in this farm amounts to an average of 2.5 tons/ha, some intensive ponds however, yield up to 7 tons/ha. It should be noted that most of this weight gain (some 4.9 tons) is due to the natural and wastewater substrate contained in the pond water, 1. 1. tons of the fish mass is attributed to fodder addition, while remaining 1 ton is the weight of the fries used for growth.

As an additional advantage duck-weed (Lemna minor) is harvested from the ponds routinely and given to the swines as fodder. Experiments are now conducted on the introduction of mixed cultures of carp and grass carp to the pond system, in order to get additional gain in fish weight and simultaneously to combat the higher plants growth problem.

Another interesting example of aquaculture is served by a primary plant for the city of Staszów, discharging the effluent either to fish ponds or to heavily irrigated poplar plantations. The layout of the system is presented in fig. 8. The wastewaters are aerated by simple cascades before entering a series of ponds. The ponds are carefully managed, with controlled dosing of the retained wastewater, adjusted dilution with ditch water, as well as with regular duck-weed harvesting and higher plants collection. It should be noted that there and at other fish farms, small fry was a much better stocking material than fingerlings. The yields were comparable to those obtained with the full-size fish.

It is obvious that in many regions of this country the natural methods of tertiary treatment cannot be applied due to the shortage of the adequate land and volume of wastewaters to be treated. As to the Silesia region, probably the most heavily industrialized area in Europe, there are on-going projects to construct physico-chemical water reclamation stations totalling some 7.7 $m^3/s$ of flow-through capacity [9]. The reclaimed water will supply the heavy metallurgical industry, machine factories and coke plants. The treatment proces-

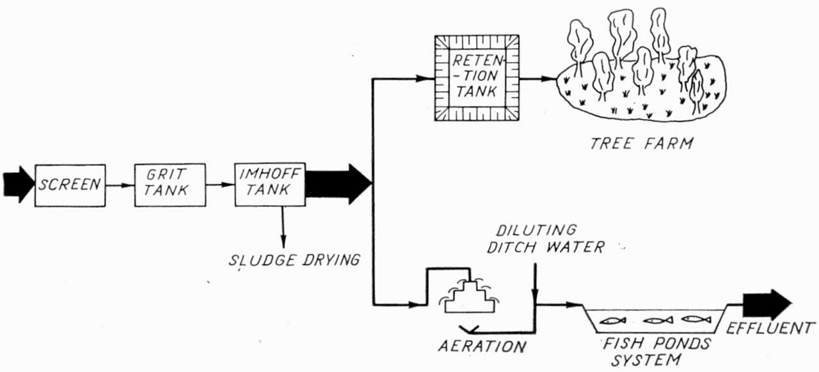


Fig. 8. Existing municipal sewage treatment plant with fish ponds and a tree farm as methods of tertiary treatment

Rys. 8. Oczyszczalnia miejska, w której stawy rybne i uprawy topoli spełniają rolę trzeciego stopnia oczyszczania

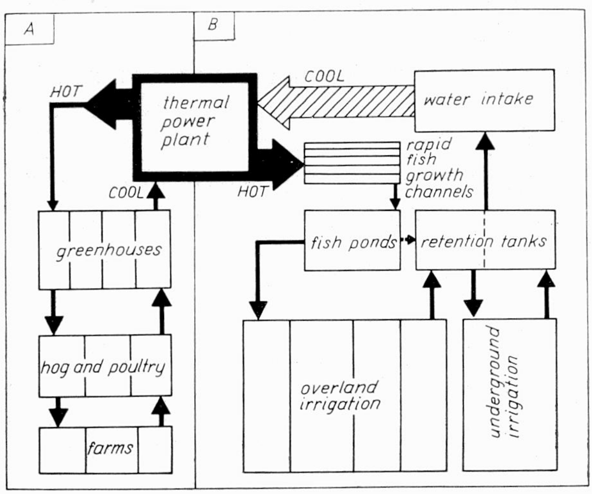


Fig. 9. Utilization of thermal discharges from power plants:
A) small cycle connected with greenhouses and animal production, B) large cycle connected with aquiculture and fish farming

Rys. 9. Wykorzystanie ciepła odpadowego z elektrowni:
A) mały obieg ze szklarniami i ogrzewaniem ferm zwierzęcych, B) duży obieg z gospodarką rolną i rybną

ses include nitrification-denitrification, coagulation, decarbonation, filtration and disinfection. These methods of industrial reuse of wastewaters are still relatively new considering that the full scale examples are practically limited to the Bethlehem Steel Co. in Baltimore, municipal plants for South Lake Tahoe, Santee, Lancaster, Orange Country in USA, or to the use of biological effluent for cooling purposes.

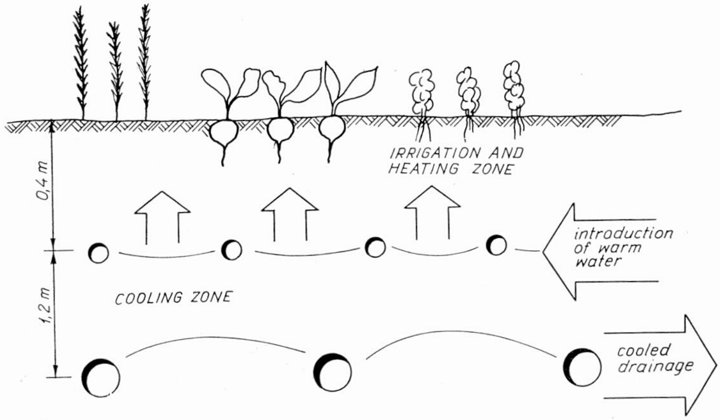


Fig. 10. Layout of underground irrigation with thermal discharges
Rys. 10. Schemat nawodnień wodami podgrzanymi

### 3.4. IN-SITU AUGMENTATION OF WATER QUALITY

There are various methods of in-situ control, development and augmentation of water quality, practiced presently in this country, e. g.: bleeding discharge of the saline, and acidic mine discharges according to the flow-rate distribution, low weir aeration and artificial surface aeration of rivers, monitoring of pollutant waves and the time of passage, related operation of waterworks; etc. Those are well known techniques; the novel ones worth mentioning here concern reclamation of aquatic habitats in natural lakes.

Poland has about 9300 lakes totalling some 3200 km$^2$, i. e. 1% of the country's surface area. Some of the lake districts, such as the famous Mazurian Lake District with its 1063 lakes, where the largest ones have areas around 11 000 hectares, suffer from tremendous pressure from the tourist industry, fisheries, and agricultural runoff. These factors enhance the eutrophication processes to such an extent that the accelerated ageing takes place within a few decades. Now the concept is to establish and protect the wilderness areas with minimum human access, in order to retain the "zero class" water quality (natural and totally unpolluted) — for human consumption and providing the pressure outlet at eutrophic, reclaimed or artificially maintained reservoirs.

The methods of reclamation of eutrophied reservoirs are presented in fig. 12 [22]. Part a demonstrates the cutting of non-point sources and point discharges inflows to the lake by circumferential ditches that empty below the dam in impounded reservoirs or in any of the natural outlets. The eutrophied lakes may be also forced to exchange the volume of the nutrient rich waters by artificial pumping, such as presented in fig. 12 b. Both methods may be supplemented by hypolimnion aeration and /or sludge withdrawal. The sludge is usually utilized agriculturally.

The most original method — which has been implemented with considerable success since 1968 [22] — is presented in fig. 13. The endangered lake is cut off from the nutrient

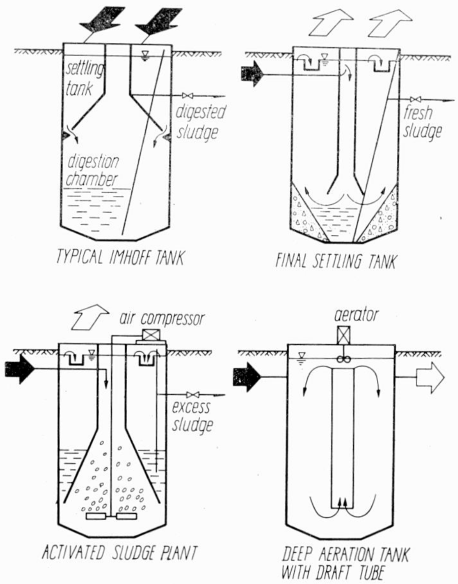


Fig. 11. Methods of upgrading primary Imhoff tanks

Rys. 11. Metody poprawy efektu oczyszczania w osadnikach Imhoffa

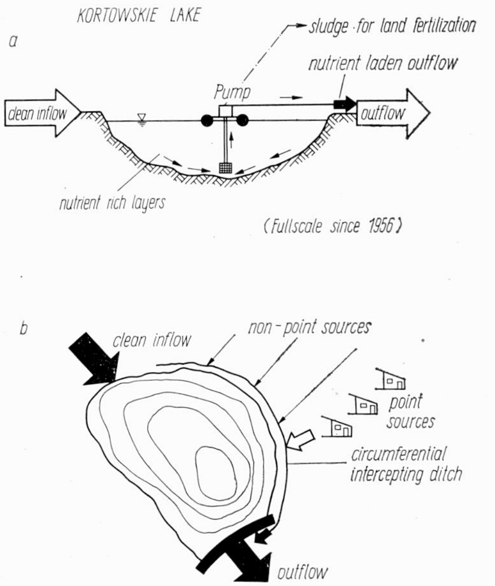


Fig. 12. Technical methods of eutrophication control used in Poland

Rys. 12. Metody techniczne ochrony jezior przed eutrofizacją w Polsce

sources by circumferential ditches. Simultaneously a protective coniferus trees belt (pines in Polish conditions) is established in order to provide a large volume of humic acids produced as a result of the decay of the needle litter. The humic compounds (fulvic and similar acids) react with nutrients and precipitate to the bottom [22]. The process is not so long as it might be considered to be, provided that the fresh inflow of nutrients is curtailed. In one instance, Lake Biksze — a shallow, highly eutrophic flow-through lake — has been reclaimed by cutting the circumferential ditch and leaving the peat belt around the lake to do the job. Peat leaches humic substances of somewhat smaller affinity for nutrients. Within five years, however, the transparency of the lake went gradually up, from 0.4 to 2.5 m.

The Maria Skłodowska-Curie Fund (MSC F) — joint undertaking of the Polish and American Governments — sponsors, among numerous researches, a project on technical reversal of the eutrophication process on two adjoining lakes, where the ageing, accelerated by primary wastewater effluent discharge, came a full cycle. At present it is observed that the lakes, where fish production was measured in hundreds of kilograms per hectare just two years ago, have become biologically devoid of economically attractive species, including forms of lower animal organisms. The project [20] involves the pumping of sludge and its discharge on land in liquid and dewatered forms (by centrifuges installed on floating platforms). The two forms of sludge are used, because appropriate land (i. e.

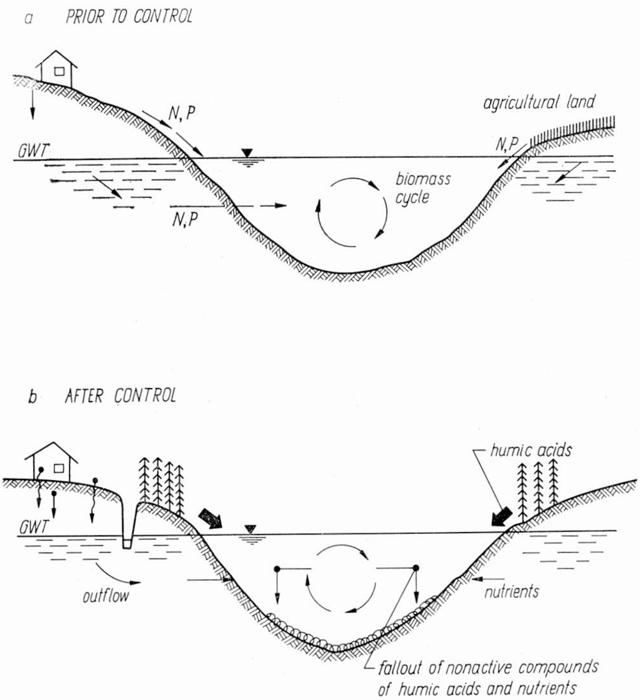


Fig. 13. Method of eutrophication control based on precipitation with natural humic compounds

Rys. 13. Metoda kontroli eutrofizacji oparta na strąceniu naturalnymi związkami humusowymi

sandy loam and other light type permeable soils) is not alway available in the vicinity of the lakes. The sludge is found to be quite stimulating to the plant growth, adding, moreover, texture and body to the irrigated sandy soils.

Another project, also within the MSC Fund, is oriented towards the utilization of the non-point source (NPS) discharge of excess nutrients from surface run-off [19]. The concept, illustrated in fig. 14, consists of drainage ditches and an intercepting lateral ditch discharging to the algal-bacterial ponds which then feed the fish ponds. In favourable weather conditions the nutrients may be recycled back to the irrigation system for further utilization.

### 3.5. UPGRADING OF THE EXISTING WATER POLLUTION CONTROL FACILITIES

With a long history of wastewater treatment and a tremendous economic development of Poland in the post-war period, the majority of older treatment facilities are now out-dated, overloaded or providing insufficient level of organic load removal. Thus, simultaneously with the design and erection of new facilities, a large expertise had to be developed in upgrading or low-budget reconstructing of the existing plants. The point in these activities is to present a plan for upgrading that would account for unskilled labour locally available, being cost-effective when compared with the ready-made equipment.

The simplest means include the elimination of operational inconsistencies at existing units, such as final clarification upgrading through labirynth weirs, Meyernoth inlet pipes, stone beds, etc.

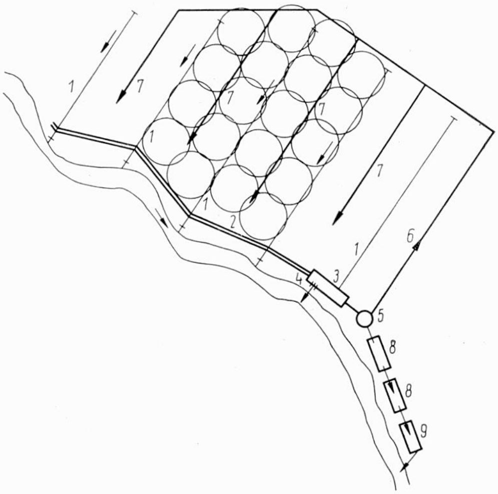

Fig. 14. Irrigation-drainage system of NPS pollution control through closing the biogenic cycle

*1* — existing drainage ditches, *2* — new lateral ditch, *3* — accumulation pond, *4* — overflow, *5* — pump station, *6* — main recycle pressure conduit, *7* — spray irrigation laterals, *8* — algal-bacterial pond, *9* — fish ponds

Rys. 14. System nawadniająco-odwadniający kontroli zanieczyszczeń obszarowych przez zamknięcie obiegu materii

*1* — istniejące rowy odwadniające, *2* — rów boczny, *3* — staw akumulacyjny, *4* — przepływ, *5* — stacja pomp, *6* — główny przewód ciśnienia obiegowego, *7* — ukośne odgałęzienie przewodu zraszającego, *8* — staw bakteryjno-glonowy, *9* — staw rybny

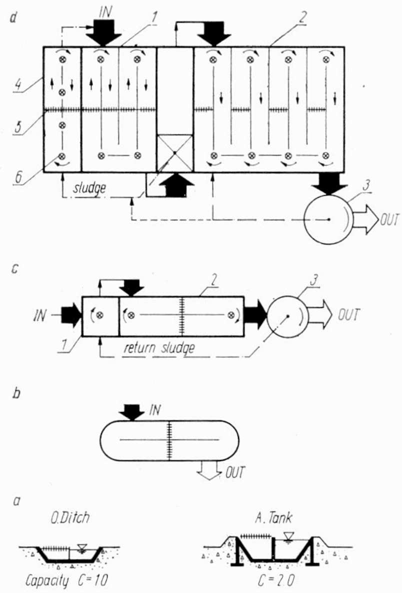


Fig. 15. The Promlecz modular treatment plants in UNIKLAR-77:

*a* — doubling the capacity of conventional oxidation ditch into an aeration tank, *b* — typical oxidation ditch used for loads below 2000 PE, *c* — two stage typical activated sludge plant for loads below 15 000 PE, *d* — two stage modular activated sludge plant with intermediate settling and separate sludge conditioning for up to 200 000 PE:

*1* — I-st stage tanks; *2* — II-nd stage tanks; *3* — final clarifier; *4* — sludge digestion tank; *5* — rotor brush aerator; *6* — turbine aerator — Potap

Rys. 15. Oczyszczalnie Promlecz w systemie UNIKLAR-77:

*a* — podwojenie przepustowości rowu biologicznego, *b* — typowy rów biologiczny dla RLM 2000, *c* — dwustopniowy osad czynny dla RLM 15 000, *d* — dwustopniowy osad czynny z podwójną sedymentacją i wydzieloną stabilizacją osadu:

*1* — I. stopień, *2* — II. stopień, *3* — osadnik, *4* — komora stabilizacji osadu, *5* — szczotki, *6* — aeratory Potap

The importance of the proper control of final sedimentation and sludge recycle as well as suspended solids removal in existing facilities cannot be overemphasized. The suspended solids in the final effluent contribute to 15–35% of the total BOD load carryover. Thus, their adequate removal alone constitutes a significant upgrading of effluent quality. The upgrading measures mentioned above should be regarded as minor constructional changes. More complex operational changes — able to eliminate the varying hydraulic loading which results in detrimental pulse operation of the settling tanks and flocs carryover — include the introduction of parallel (bleeding) equalization tanks, the smoothing of the pumping operation by increasing the number of pumps and decreasing their individual outputs, etc., and can also be carried out without large scale investments.

Other elaborate changes in the treatment plant technology would include adjustment of the activated sludge loadings, filter media replacement (plastic for stone), recirculation of wastewaters, etc. An example of such changes is offered by a plant with anaerobic lagoon that has been simply converted to an aerated lagoon which in turn — after addition of the final clarifier — has been converted to an activated sludge plant. Thus, with a small cost, the wastewater treatment efficiency went up from 50% BOD removal to almost 90%. On the other hand, loadings applied to the activated sludge process may be successfully changed, thus providing an increase of flow through capacity of the treatment plant by sacrificing somewhat the effluent quality and efficiency of the BOD removal. This change from an extended aeration plant down to the contact stabilization process is practiced at smaller wastewater treatment plants [17].

An example of modifications to the Imhoff tank, a standard primary treatment unit in Europe for more than half a century, is presented in fig. 11. Various modifications of this type of plant are now in full operation in Poland providing effluent treatment efficiency improvement from 30% to 85–90% removal of $BOD_5$.

Other upgrading techniques involve pressure flotation in place of primary settling, coagulant addition to final clarifier influent, improvement of biotreatment through selective adsorption of toxic substances (introduction of activated carbon), enzymatic stimulation (e. g. for faults control), tube clarification, coke biofiltration and natural (intensive irrigation and soil filtration beds) as well as artificial (i. e. physico-chemical) tertiary treatment.

### 3.6. UNIFIED SYSTEM OF WASTEWATER PLANT DESIGN RECOMMENDATIONS

The main purpose of the research conducted in Poland for a long time is: to decrease of time from design to erection of waste treatment facilities, to simplify the construction and to decrease costs, manpower and material consumption. The reason behind this approach was to consolidate the dispersed time consumming efforts for originality in design, which yield additional difficulties in erection, in conditions where the need calls for urgent introduction of basic secondary treatment. To meet these requirements the UNIKLAR-77 System has been introduced. It is based on typical industrial dimensions of prefabricated or made on-site elements of wastewater treatment plants. This unification is carried out by using

— system approach to the design construction and production of mechanical equipment and elements of the wastewater treatment plant;

— standarized technologies and auxilliary equipment.

An integrated-interdisciplinary unit has been formed for the coordination of research, development, and start-up of manufacturing of the unified elements to be used in wastewater treatment plants. Within the UNIKLAR-77 system the plants have been divided into three size categories: 100, 20 000 and 200 000 population equivalents (PE). Due to the specifics of both technology and construction engineering of the very large plants, above the 200 000 PE, the unified system encompasses only basic dimensions of the treatment units [7].

The basic purpose of this system is the development of unified large-scale manufacturing of the treatment equipment and structural elements, based on serial catalogues for the three size categories. Two prefabrication techniques used are: prestressed elements and cable prestressing of units. Independently, methods of industrial monolithic structures manufacturing are used with typical reusable wood plankings.

The UNIKLAR-77 has introduced modular approach to the design of facilities, based on typical single or multi-functional units. As an example of the market series of package plants BIOBLOK A and B are offered for the first and second size categories. The first series — B is offered in modules 25, 50, 75 and 100 $m^3/d$, while type A series goes up to 600 $m^3/d$. The processes used include extended aeration tanks (series B) and activated sludge tanks whose loading is higher than 0.05-0.1 kg $BOD_5$/kg MLVSS day (series A) [6]. The latter series is then equipped with sludge stabilizer, as shorter detention (12-24/hrs) does not provide for adequate auto-oxidation of excess sludge. Although technologically speaking there is nothing new in these plants, they are mentioned here since they constitute the first package plant-modular offer designated for standard use on international scale in East European countries.

Novel technological and constructional solutions, for larger capacities, include the series of oxidation ditches and aeration tanks offered within the UNIKLAR-77 system by PROMLECZ [23]. The system encompasses capacities from 1000 to 200 000 PE and the $BOD_5$ loads up to 10 000 kg $O_2$/d and higher, and is designed for treatment of both strong food industry wastes and domestic sewage. The PROMLECZ's offer within the UNIKLAR-77 includes oxidation ditches with worm type (or Goliath type) rotor brushes with oxygenation capacities of up to 3 kg $O_2$/KWh, and deep aeration tanks — whose plan view is similar to the oxidation ditches — equipped with rotor brushes together with patented Potap turbine aerators. The latter can introduce up to 50 kg $O_2$/hr at $E = 2$–5 kg $O_2$/kWh. The depth of the aeration tank is 2.5–3.0 m. The Potap aerators are placed directly over the partitioning walls of the activated sludge tanks, thus one aerator serves two compartments. Another combination is presented in fig. 15 where the turbine aerators are located over the partitions and at the turns of the ditch like in aeration tank. The patented design yields 30% operational cost savings, becoming apparent at higher throughputs.

The capital costs are also significantly reduced due to the modularity of standardized design and lower material consumption. The standardization of dimensions does not mean rigidity of technology — otherwise the effects would become questionable. The dimensions are standardized for various types of activated sludge systems, in other cases the preferred dimensions are recommended. Trickling filter structures are also standardized as well as screens, grit tanks, primary and secondary settling tanks, concrete and earthen digestion tanks, vertical and radial thickeners, sludge lagoons, aerated lagoons, oxidation ponds and other facilities. The dimensional uniformity is necessary because of mechanical equipment already marketed, such as screens, scrapers, pumps, aerators, etc.

### 3.7. COMBINED WASTEWATER TREATMENT FACILITIES

An advantage of the centralized funding system for water and wastewater management is the possibility of joining various interested water users towards investment in a combined wastewater treatment plant. The existing regulations encourage the design engineer to think in terms of large areas and regions. Thus, each large waste treatment project is preceded by an economic optimization analysis of initial and operational costs of various alternative combinations of industrial and municipal discharge. In large scale, this has been done for urban agglomerations of Gdańsk, the region of Kalisz, the Upper Silesia mining complex, the Sudety Mountains development project, Szczecin and environs and other places. There are specific advantages of wastewater treatment in combined, central or regional wastewater plants. The elements that are included in the optimization analysis are of technical, economical, and non-economical nature:

— costs of sewers, both gravity and pressure, are usually smaller than those of the individual treatment plants;

— the maintenance and running costs of regional plants are usually lower than a sum of individual plants running costs;

— the large plant size allows to employ highly skilled personnel and laboratory staff;

— the large plant size allows to use highly sophisticated technology and precise automation equipment;

— combination of various industrial effluents with sanitary sewage permits self-precipitation, decreases nutrients requirements, and gives a much more even loading to the biotreatment stage;

— at larger plants adequate effluent quality control and monitoring, on a continuous basis, is much easier to be maintained;

— the location of the combined treatment plant is selected bearing in mind minimization of environmental impact on air, water and soil in order to create optimum disposal conditions;

— the larger volume of final effluent the more favourable are conditions for reuse in the local industrial plants.

Frequently the adequate protection of surface water intakes was the only decisive factor in favour of grouping waste discharges in conditions where economic calculations and indices were even on all variants [18]. From the observations on secondary biological plants completed recently for the cities of Częstochowa and Opole as well as plants being in operation for several years, it follows that some of the factors, unaccountable for in the economic analysis, such as skilled manpower and adequate sophisticated control equipment installed at larger plants, may become responsible for excellent treatment of combined industrial and municipal effluent. The two plants mentioned above, designed respectively for 70 000 and 110 000 $m^3$/d, have adopted a rather typical technology of activated sludge with $F/M = 0.2$–0.4 kg $BOD_5$/kg MLVSS day, at sludge concentrations of 3000–4000 mg/$dm^3$. Both surface and compressed air aeration is practiced in such plants. The resulting effluent concentrations of 10–15 mg $O_2/dm^3$ — $BOD_5$ exceed the expectations when one considers the heavy metals, detergents and phenol loads contributed by industrial effluents.

When discussing combined treatment plants, one should mention the approach, which has been assumed in Poland, to the solution of the problem of rural sources of pollution. As a routine, introduced by the Institute, economical optimization analysis is run on combined versus individual household wastewater treatment systems [19]. The shortest route intercepting sewers designed subsequently, are followed by the combined treatment plant for a group of villages and small towns. Such plants offer a simplified technology of the extended aeration with high sludge ages minimizing the sludge disposal problems, coupled usually with the agricultural use of effluents or fish ponds and paralelled with the high rate soil filtration. In order to facilitate the local rural initiative, the plants, usually within the range of 200 to 2000 $m^3$/d, consist of earthen basins with reinforcement made of locally available materials and equipment.

### 3.8. ANIMAL WASTEWATER TREATMENT

Of the many industrial wastewater treatment problems in this country, the treatment and disposal of the effluents from large scale animal farms, appear to be the most important ones. Extremely rapid development of the technology of industrial scale animal farming and the introduction of water cleaning and transporting system in the farms have created significant problems of the adequate treatment of highly concentrated effluents, where $BOD_5$ ranges from 6000 to 15 000 mg $O_2/dm^3$ and the volumes approach 800 $m^3$/d.

The problem will be discussed here with respect to the hog farms which are usually erected in three sizes: 12, 24 and 36 thousand hogs. Due to their frequently unfavourable location from the viewpoint of agricultural utilization of effluents, full scale, multistage treatment is usually applied in order to obtain effluent suited for surface water discharge. There are several wastewater treatment systems being now in operation that utilize chemical (alum) coagulation, activated sludge treatment, filtration and disinfection. Other systems involve multi-stage activated sludge or multi-stage lagoon treatment.

Even though most of these systems attain required effluent quality the economics of the processes used is unfavourable. For these reasons research and development is now conducted on advanced reuse and recovery technologies for application in animal wastewater treatment.

The research includes thermophilic aerobic digestion of ruminant and non-ruminant manures and anaerobic digestion in a contact stabilization made with sludge return. Fig. 16 presents a unique yeast manufacturing system, following an initial breakdown of

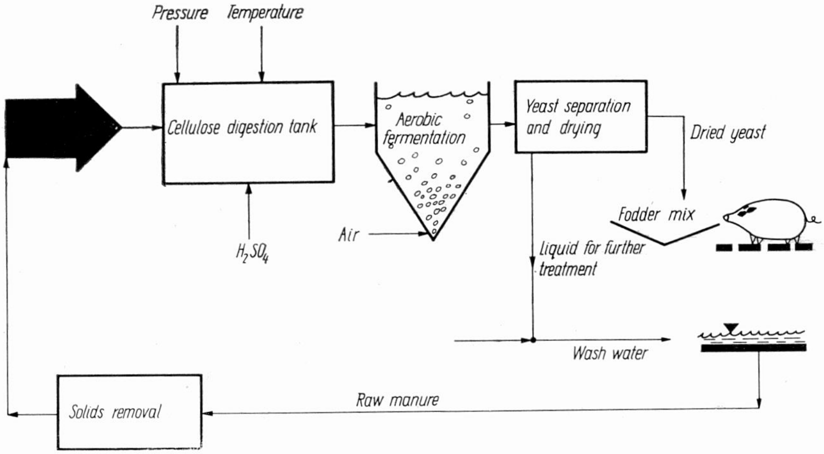


Fig. 16. Aerobic fermentation treatment of hog manure
Rys. 16. Fermentacja tlenowa gnojowicy świńskiej

undigestible and nonfermentable materials into easily biodegradable carbohydrates. The systems, though in experimental stage, have good chances to be adopted due to the continuously rising costs of meat production, coincidental with fodder and energy costs increase. It should be noted that all studies, done so far on the single cell protein (SCP) recovery have proved excellent feed capacities of the biomass recovered from both the anaerobic and aerobic fermentation, when mixed in proper composition with the basic fodder [16].

## 4. INTERNATIONAL COOPERATION

The history of this countrys involvement in the international water pollution control projects dates back to the early sixties. The realized development and demonstration projects sponsored by the United Nations concerned protection of surface waters against organic pollution, thermal discharges, and mine drainage effluents. Later on the projects were launched on the whole river system (Vistula River).

One of the most interesting international programmes being carried in Poland is the Comprehensive Environment Programme (POL/CEP) realized, under auspices of the United Nations Development Programme, in the Upper Silesia region. The programme is one of the first of its type in the world and is aimed at the definition and solution of interdependent problems of water, air and soil pollution in large, heavily industrialized, regions. Within the Programme five major topic groups may be outlined:

— development of the environmental information system in respect to air, soil and water ecosystems (information banks);

— development of technologies for decreasing the pollution load by applying the biological and physico-chemical methods in all three phases of the environment;

— elaboration of an integrated-regional plan for the control of pollution of the three environmental components;

— design and installation of regional monitoring systems for air, water and soil surveillance; including data processing and interpretation;

— definition of the influence and effects of air, soil and water pollutants on man and his environment.

The POL/CEP programme, realized by the Research Institute for Environmental Development, encompasses over 150 various individual topics on all aspects of environmental pollution control.

A large group of projects is presently realized within the M. Skłodowska-Curie Fund (MSCF). A section of MSCF, sponsored jointly by US Environmental Protection Agency and the Polish Ministry of Economics and Environmental Protection, encompasses a host of topics of interest to both funding parties, namely: the agricultural utilization of effluents and sludges, the river wastewater treatment plants in heavily overpopulated and industrialized regions, reclamation of strip mines, heavy industry wastewater treatment technologies, and many others.

## 5. SUMMARY AND CONCLUSIONS

The presented status of the art of the water pollution control activities in Poland is by no means thorough or complete. An attempt has been made to present individual examples of those achievements that will be helpful for the advancement of science and engineering in the water pollution control field. An attempt has also been made to present certain general trends and tendencies in the management of water resources in this country — of their quality and quantity.

The paper has been confined only to the end-of-pipe water pollution abatement technologies. The in-plant reductions of the raw waste loadings, the in-shop technological changes, the economical policy in the regions, as affected by anticipated environmental impact have not been discussed within the space allotted. All of these activities, when coupled with the high standard of know-how in the wastewater treatment field contribute to the continuous improvement of the country's aquatic habitat.

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## OCHRONA WÓD W POLSCE PRZED ZANIECZYSZCZENIEM

W artykule omówiono podstawowe problemy ochrony wód w Polsce, biorąc pod uwagę zmniejszenie przewidywanego na lata osiemdziesiąte deficytu zasobów wód powierzchniowych. Po omówieniu zasad i metod zapisu kontroli jakości wód w kraju przedstawiono techniczne metody oczyszczania, wykorzystania i odnowy ścieków. Omówienie ograniczono do rozwiązań i metod najciekawszych z punktu widzenia rozwoju technologii ochrony wód na świecie. Przedstawiona została technika rolniczego wykorzystania

ścieków jako metoda drugiego i trzeciego stopnia oczyszczania w połączeniu z intensywnymi uprawami drzew i stawami rybnymi. Następnie zwrócono uwagę na praktykę rekultywacji i odnowy jezior poprzez odcięcie dopływów punktowych i rozproszonych oraz sadzenie drzew szpilkowych lub odkrywki torfowe, jako źródło kwasów wchodzących w reakcję ze związkami biogennymi. Metodom naturalnym ochrony wód poświęcono wiele projektów realizowanych wspólnie w ramach Funduszu Marii Curie-Skłodowskiej. Techniczne aspekty budowy nowych oczyszczalni ścieków omówiono na przykładzie systemu Uniklar 77, rozwijając w szczególności zagadnienie analizy poprzedzającej celowość grupowania źródeł zanieczyszczeń w oczyszczalniach centralnych i regionalnych.

W zakończeniu zwrócono uwagę na zaangażowanie krajowego potencjału naukowo-badawczego w pracach ONZ i w międzypaństwowych umowach dwustronnych.

## DER GEWÄSSERSCHUTZ IN POLEN

Der Beitrag diskutiert diverse Probleme des Gewässerschutzes in der VRPolen, wobei die erwartete Verminderung des Angebots an Oberflächenwasser in den 80-igen Jahren bereits berücksichtigt ist.

Neben einem Überblick über die Gütekontrolle der Gewässer, beinhaltet der Beitrag einige Gedanken zur Abwassernutzung und Wasserrückgewinnung; die Übersicht beschränkt sich aber auf Verfahren, die modern sind und interessant erscheinen. Als 2. und 3. Reinigungsstufe, werden natürliche, mit der Landwirtschaft verbundene Reinigungsverfahren vorgeschlagen. Anschliessend kann das Abwasser in Baumschulen und in Fischzuchtteichen genutzt werden.

Die Rekultivierung von Seen kann auf verschiedene Weise erfolgen. Sie ist u. a. durch das Absperren der punktförmigen und verstreuten Speisequellen, durch den Anbau von Nadelbäumen und durch den Abbau von Torfwiesen zu erzielen. Huminsäuren des Torfes reagieren hier mit den eutrophierenden Nährstoffen.

Im Rahmen des polnisch-amerikanischen Maria Curie-Skłodowska Fonds, sind den naturmässigen Methoden des Gewässerschutzes mehrere Projekte gewidmet. Technische Gesichtspunkte des Baues von neuen Kläranlagen sind am Beispiel des Systems UNIKLAR 77 dargestellt; die Notwendigkeit einer vorangehender Analyse wird speziell beim Bau von Zentral- und Gruppenkläranlagen unterstrichen.

Abschließend wird auf das wissenschaftliche Potential hingewiesen, welches in Arbeiten der Vereinigten Nantione und bilateralen Vereinbarungen mitwirkt.

## ОЧИСТКА ВОД В ПОЛЬШЕ

Обсуждены основные проблемы защиты вод от загрязнений в Польше с учетом необходимости снижения в 1980-е годы дефицита ресурсов поверхностных вод. После изложения принципов и методов записи контроля качества воды представлены технические методы очистки, использования и регенерации сточных вод. Обсуждение ограничивается решениями и методами, относящимися к наиболее интересным с точки зрения технологии водоподготовки в мире.

Описана техника сельскохозяйственного использования сточных вод как метод второй и третьей степени очистки в сочетании с интенсивным деревонасаждениями и рыбными прудами. После этого обсуждена практика рекультивирования и регенерирования озер путем отсечения точечных и рассеянных притоков, а также насаждения хвойных деревьев и применения открытых торяных выработок в качестве источников кислот, входящих в реакцию с биогенными соединениями. Естественным методам водозащиты посвящены многие проекты, реализуемые в рамках Фонда Марии Склодовской-Кюри. Технические аспекты построения новых очистных сооружений обсуждены на примере системы „Юниклар 77" с уделением особого внимания анализу вопроса об определении целесообразности группирования источников загрязнений на центральных и региональных очистных заводах.

В заключении уделено внимание участию отечественного научно-исследовательского потенциала в работах ООН и в реализации двусторонних международных договоров.