Applicability of Sewage Ponds, with Special Attention to the Purification of Organically Soiled Sewage in Rural Districts

Schmidt, G. P.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20386635
Technical Translation (National Research Council of Canada), 1968

NRC
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NATIONAL RESEARCH COUNCIL OF CANADA

TECHNICAL TRANSLATION 1342

THE APPLICABILITY OF SEWAGE PONDS, WITH SPECIAL ATTENTION TO THE PURIFICATION OF ORGANICALLY SOILED SEWAGE IN RURAL DISTRICTS

BY

G. P. SCHMIDT

FROM
WISSENSCHAFTLICHE ZEITSCHRIFT DER
ERNST - MORITZ - ARNDT - UNIVERSITAT GREIFSWALD
14: 77 - 111, 1965

TRANSLATED BY

D. A. SINCLAIR

THIS IS THE ONE HUNDRED AND SEVENTY - FIFTH OF THE SERIES OF TRANSLATIONS
PREPARED FOR THE DIVISION OF BUILDING RESEARCH

OTTAWA

1968

PREFACE

This paper describes the possibilities of natural biological purification of sewage from small communities by the sewage pond method giving consideration to technically simple solutions.

Mr. Schmidt states that besides being hygienically reliable, this method is economical, and hence worthy of greater attention in the future.

The subject is dealt with under the following headings:

1. Definitions of the most important concepts pertaining to the sewage pond methods (suggestions for standardization).
2. An outline of the problematics and mode of operation of the sewage pond method, and
3. Descriptions of technically simple variants of sewage ponds, with consideration given to their hygienic and economic factors.

The Division wishes to records its thanks to Mr. D. A. Sinclair, Translations Section, National Research Council, for translating this paper and to Mr. D. A. Lutes of this Division who checked the translation.

Ottawa
September, 1968

R. F. Legget
Director

NATIONAL RESEARCH COUNCIL OF CANADA

Technical Translation 1342

Title: The applicability of sewage ponds, with special attention to the purification of organically soiled sewage in rural districts

Zur Anwendbarkeit von Abwasserteichen unter besonderer Berücksichtigung der Reinigung organisch verschmutzter Abwässer ländlicher Siedlungen

Author: Günter P. Schmidt

Reference: Wissenschaftliche Zeitschrift der Ernst-Moritz-Arndt-Universität Greifswald, 14: 77-111, 1965

Translator: D. A. Sinclair, Translations Section, National Science Library

THE APPLICABILITY OF SEWAGE PONDS, WITH SPECIAL ATTENTION TO THE PURIFICATION OF ORGANICALLY SOILED SEWAGE IN RURAL DISTRICTS

1. Sewage Purification Plants in Rural Communities and Methods of Investigation

1.1 Sewage purification plants

Agriculture is undergoing a world-wide transformation, inasmuch as the large farm is everywhere becoming the rule, since only through large-scale operation can rational working methods and techniques be applied. This often results in concentrations of livestock. Hygienists, hydrologists and others therefore face new tasks of water purification or treatment of droppings.

Moreover, the accumulation of sewage in rural communities has greatly increased in recent years through the improvement of drinking water supply from small waterworks and pipelines, and also through the existence of modern dwellings with toilets, baths and showers. Whereas formerly there was hardly any accumulation of faecal household sewage and the waste waters were generally allowed to seep uncontrolled into the ground in the vicinity of the dwelling areas, today sewage treatment has become essential. Since the conditions for sewage purification may be much more complex in rural communities than in cities, owing to the low building density and sometimes even a scattered arrangement, close cooperation is needed between medical and veterinary hygienists and hydrologists for the determination of optimum solutions.

At the present time the purification of sewage from rural communities with a subscription level up to 2500 population equivalent (PE) is not always hygienically and economically executed. Nevertheless on the basis of local circumstances sewage purification and even utilization has to be made economically defensible and hygienically satisfactory.

At present there is much discussion about mechanical and partially biological and totally biological sewage purification plants.

Mechanical and partially biological purification plants in the form of various types of sedimentation tanks, Schreiber domestic sewage treatment plants, and similar installations, must be termed "hygienically doubtful" with respect to their purification effectiveness. According to recent bacteriological and chemical investigations of the input and output of more than 200 domestic purification plants in the vicinity of Neubrandenburg, carried out by the Directorate of Water Conservation of Küste-Warnow-Peene, Stralsund, and unsatisfactory purification effect was repeatedly noted.

Grahneis[35] reaches similar conclusions after extensive investigations in East Germany, and remarks: "Owing to defective mechanical clarification of the often very high load of sewage (permanganate consumption varies between 90 and 780 mg litre, and averages 300 mg litre) and the unfavourable bacteriological findings, this type of sewage treatment does not meet hygienic requirements, because the sewage should be rotted, i.e. biologically broken down."

The partially biological and wholly biological assistance in the form of various types of bio-oxidation and activated sludge channels, total clarification plants according to Kehr[53], bio-filters, sewage ponds, etc., are more reliable from the hygienic point of view. Bio-oxidation channels, in particular, have recently attracted attention as biological purification plants for small cities and rural communities. In bio-oxidation channels, indeed, a good BSB_5 breakdown* is often obtained, but they are generally unsatisfactory in their bacteriological effectiveness. Knaack[56] made a special investigation of the operation and effectiveness of bio-oxidation channels at numerous installations in East Germany, and very correctly recommends that no further such channels be constructed until the aeration units have been improved so that they are less subject to breakdown and then in every case an increased oxygen input is attained, whereby the biological processes and hence also the bactericidal effectiveness can be intensified. Frequently bio-oxidation channels are underloaded, and this can also impair their efficiency. However, properly operated bio-oxidation channels are hygienically reliable[109]. It has long been known abroad that bio-oxidation channels in the form developed by Dr. Pasver of Holland, do not always meet the hygienic requirements.

Collom and Hicks[42], for example, compared various purification methods in 1958 and gave very informative figures on sewage purification and also on the effectiveness of bio-oxidation channels, as may be seen in Table I. The bio-oxidation channels do not work satisfactorily in respect to reduction of the coliform germ counts; they are comparable in their bactericidal effect with mechanical purification plants. Oxidation ponds, on the other hand, purify sewage satisfactorily from a hygienic point of view, after the sewage has been in them for a few days.

The common mechanical sewage purification plants may be expected to lose their importance progressively owing to their deficiencies with respect to

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* BSB_5 = five-day biochemical oxygen consumption = BOD_5

purification effect in the execution of "complex hygiene melioration"[98] This expression refers to measures which contribute to the limitation of a number of health and efficiency limiting factors of the environment. These hygienic meliorations are comparable with the "environment sanitation" that has become familiar in the literature. Increasingly simple, more or less automatic biological systems of sewage purification for rural settlements must be developed, scientifically investigated and systematically applied. The total clarification plants developed in the Institute of Water Conservation of the Technische Hochschule Hannover, which is basically a development parallel to the American "extended aeration", deserves special attention in this connection. In principle it is a biological sewage purification plant employing sludge mineralization (similar to the bio-oxidation channel), which is capable of purifying the sewage in a completely hygienic manner in just a few hours in a combined tank comprising a rectangular aeration tank and a subsequent clarification compartment. This trend appears very promising and experiments with the activated sludge tank designed by the Stralsund Water Conservation Directorate, which represents a further development of the total clarification plant, should be stepped up.

In the present paper we shall describe possibilities of natural biological purification of sewage from small communities by the sewage pond method, with consideration of technically simple solutions. Besides being hygienically reliable, this method is very economical, and hence should receive greater attention in the future.

The subject will be dealt with under the following headings:

1. Definitions of the most important concepts pertaining to the sewage pond method (suggestions for standardization).
2. An outline of the problematics and mode of operation of the sewage pond method.
3. Descriptions of technically simple variants of sewage ponds, with consideration of their hygienic and economic factors.

1.2 Discussion of solutions adopted

To clarify the problems broached in the introduction, the following methods were applied:

1. Study of the most important technical literature published in Germany and abroad.
2. Examination and appraisal of operational results in the Blankenfelde/Berlin, Dingelstedt/Hartz, Gundorf/Leipzig, Christgrün/Vogtland and Manker/Nauen sewage ponds in East Germany .

3. Consultation with governmental and scientific institutions in East Germany, West Germany and other countries.

East Germany:

Research Committee for Water and Sewage Problems in Rural Communities, Stralsund;

Scientific Foundation for Hygiene and Health in the Province of LR, Council of Ministers of the German Democratic Republic, Berlin;

Regional Hygiene Institute, Greifswald;

Zoological Institute of the Ernst-Moritz-Arndt University, Greifswald;

Water Conservation Authority, Küste-Wanow-Penne, Stralsund,

Zoological Institute of the Karl-Marx University, Leipzig;

VEB Wasserversorgung und Abwasserbehandlung Rostrock und Neu-Brandenburg;

Various governmental institutions.

West Germany:

Bavarian Biological Research Institute

Demoll-Hofer Institute, Munich;

Institute for Local Water Conservation, Technische Hochschule Hannover.

Rest of Europe:

State Hygiene Institute, Minsk;

State Hygiene Institute, Budapest;

State Hygiene Institute, Bratislava;

Local Hygiene Institute, Olomouc;

University of Nottingham, Department of Mechanical Engineering;

Institute for Health Engineering, T.N.O., The Hague;

"Andrija Stampar" School of Public Health, Zagreb;

Zoological Institute, University of Lund;

The Institute for Water Supply and Drainage, Goteborg;

Direction Générale des Eaux et Forêts, Central Station for Applied Hydrobiology, Paris.

Asia:

Faculty of Agriculture, University of Peking;

Australia and New Zealand:

University of Sydney, Faculty of Agriculture;

Auckland Metropolitan Drainage Board, Auckland.

U.S.A. and Canada:

Columbia University, New York City, Dept. of Civil Engineering and Engineering Mechanics;

University of California, School of Public Health, Berkeley;

Robert A. Taft Sanitary Engineering Centre;

Department of Health, Education and Welfare, Cincinnati;

Texas A and M University, Agricultural Extension Service, College Station, Texas;

Dept. of Agriculture, Agricultural Engineering Branch, Fredericton, N.B.;

University of British Columbia, Department of Agricultural Engineering, Vancouver.

Practical experiments of the following nature were carried out:

1. Surveying and planning of the oxidation sewage fishpond of the community of Bandelin, District of Greifswald and the Kemnitz oxidation ponds, District of Greifswald, as well as collaboration and direction in the planning of the Greifswald-Ladebow oxidation pond, Solgast, Andershof/Stralsund and the Gross-Nemerow oxidation pond in the District of Neubrandenburg.
2. Physical and chemical investigations of several sewage ponds with a view to testing the purification effect.

All physical and chemical methods of investigation employed were derived from the literature[64,38,79,109,128,132].

2. The Sewage Pond Method

2.1 Definition of terms

The application of sewage ponds to the purification of sewage has led to the adoption of certain terms, both internationally and nationally. Since the names "sewage pond", "oxidation pond", "stabilization pond", "sewage fish pond", etc. are used in the literature without exact definition, we shall deal with the most important ones here on the basis of the various authors cited and the investigations of the present author[97,98].

2.1.1 Pond (lagoon, pond)[19,122]

A shallow, drainable body of water, the pond can be artificial or can consist of natural depressions which are then used as the pond. A natural small body of water that is not drainable is more correctly called a pool; very small sewage ponds that are not completely drainable, however, should be included under the general term "sewage pond" and not "sewage pools".

"Puddles", on the other hand, are accumulations of water that dry up. Ponds and puddles are characterized predominantly by the so-called "euphotic" zone.

2.1.2 Sewage pond (sewage lagoon)[69,89,90]

Ponds which operate aerobically, anaerobically or optionally, which can be used continuously or intermittently (with or without artificial aeration). Supplementary illumination to increase the purification action is also possible. In these ponds preferably undiluted household waste waters are purified (sewage pond is the most general term). According to Imhoff[47] these are ponds (either artificially constructed or naturally present) which must process the sewage fed to them by biological self-purification processes.

2.1.2.1 Oxidation pond (oxidation pond)[90]

A sewage pond which is preferably aerobic in operation and which decomposes the contaminated substances in the secondary or supplementary sewage purification process. It can be a water reservoir for subsequent sewage filtration. The best definition as fat as we are concerned is given in "The Glossary - Water and Sewage Control Engineering" cited in Porges[90], which defines an "oxidation pond" or "sewage oxidation pond" as one into which partially mechanically or biologically pretreated sewage is introduced and is purified naturally through the influence of sunlight (production of "algal oxygen"). In the Soviet Union these ponds are called "biological ponds"[117], in Czechoslovakia "assimilation ponds"[79,92] or "accumulation ponds"[126], and in Hungary, in a somewhat modified form, "algal reaction basins"[97].

2.1.2.2 Waste stabilization pond[90]

A sewage pond which involves aerobic and anaerobic processes and preferably receives household or industrial sewage (raw sewage) which has not been pretreated either mechanically or biologically, and purifies it. Porges[90] describes this pond as follows: "This is a pond which is used for the treatment of raw sewage and in which natural biological, biochemical and physical processes lead to self-purification." Anaerobic ponds (anaerobic lagoons[87]), in which anaerobic microorganisms are principally active, can be installed upstream from them. (Gas formation, e.g. H_2S, CH_4, etc, is possible).

The manure pond (manure lagoon[19,45,52]) is a special type.

This is a sewage pond in which principally liquid and solid manures, especially from piggeries and poultry houses, are purified. Often there are two ponds, the first operating anaerobically and the second aerobically. This unit is called a "two-cell pond system". The term "manure disposal lagoon"[7,11] is also current.

2.1.3 Sewage fish ponds[67,48,24,121]

A special type of sewage pond which serves both for purification of sewage and rearing of fish. There must be a continuous supply of fresh water, in an amount of 2-4 : 1. According to Liebmann[67] the maximum permissible biochemical oxygen consumption is 0.5 kg/1000 m^2 pond area days, so that the oxygen content cannot drop below 3 mg/litre. There is then no risk of fish dying. If possible the sewage should be pretreated mechanically or by filtering through the ground. The term "sewage fish pond" is also applied to oxidation ponds in which the sewage is biologically purified and then fed to fish ponds downstream (oxidation-sewage-fish pond system).

2.1.4 Biochemical oxygen demand, BOD_5[48,19]

The BOD_5 is the amount of oxygen consumed in the biochemical reaction of the organic substance in the sewage pond at a temperature of +20°C during a period of 5 days. The amount is determined in mg/litre, g/m^3 or E · d (E = inhabitants), g/m^3 · d, g/m^2 · d, kg/ hectare · days, etc. The values contained in this work were determined after mechanical clarification of the sewage (1 1/2 hours settlement time, 35 g/BOD_5/E.d.[48]) or a load per unit volume[99] and [109] of 9 to 18 g BOD_5/m^3 pond content and more with a maximum pond depth of 1.2 m.

Lightly loaded sewage ponds are charged with 11 g BOD_5/m^2 · d, and heavily loaded ones with 10 to 45 BOD_5/m^2 · d[108]. Loads up to 100 g BOD_5/m^2 · d and more are admissible[99]. The BOD_5 in manure lagoons can be calculated accurately from the quantity of liquid manure and dung accumulating taking into account the settlement time in the mechanical clarification apparatus and the behaviour of the paste.

2.1.5 Heterotrophic organisms in the sewage pond

Bacteria, fungi, protozoa, etc., which live off organic matter and carbon dioxide, as well as inorganic compounds such as N_2, NH_3, PO_4, Na, Mg, etc., are formed, and are then used by the algae present in the pond for food or are eliminated in some other form.

2.1.6 Autotrophic organisms in the sewage pond

Organisms, preferably algae, like the genuses Chlorella and Stichococcus as well as green flagellates, e.g. Euglena and Chlamydomonas, which are capable of constructing their own body substances from organic sewage components. In particular they use carbon dioxide, phosphates, nitrogen compounds, carbohydrates in solution and salts of organic acids, whereby the concentration of soil and nutrient substances in the sewage is substantially reduced.

2.1.7 Euphotic zone[19]

The upper zone of pond water which is penetrated by light, to a depth of about 1.00 m, in which up to 99% of the accumulating light is absorbed, and in which as a consequence by far the greater part of the sewage introduced is "purified" by algae.

2.2 Applicability and Efficiency

2.2.1 Applicability

The sewage pond method is characterized by natural biological, chemical, biochemical and physical processes which are capable of purifying the sewage in a shallow pond to a satisfactory extent within a few days.

Since Caldwell's publication[10] in 1946, reporting in detail on the sewage pond method, extensive contributions on the problematics of this method have appeared in all the better known specialized periodicals.

As may be learned from the literature[1,2,4-6,8,13-16,18,22,24,28,37,41,46,47,73,88,92,111,112,114,117], sewage ponds may be found in all parts of the world - Asia, Alaska, Canada, India, China, Australia, New Zealand, Japan, United States of America, the Soviet Union, England, France, Africa, Denmark, Sweden, Spain, Hungary, Poland, Yugoslavia, Czechoslovakia, Switzerland, East Germany and West Germany.

The sewage pond method is a very old method of sewage purification, and undoubtedly the moats which surrounded the cities in the Middle Ages, served not only defence purposes, but also the natural treatment of sewage and garbage disposal, since the faeces were thrown into the moats and thus purified[24]. The first publication on the pond method appeared at the turn of the century; at that time, however, there was no planned application of sewage ponds.

At that time the idea of sewage purification in ponds was also being taken up in Germany, and Oesten[77] applied for a patent for a process involving the passage of fresh sewage first through a bacterial pond then through a crustacean pond and finally through a fish pond. On the basis of this system the fish ponds which for the most part are still operating effectively, were constructed, e.g. those of Munich[54,66], Schönerlinde, and Gross-Beeren near Berlin, to mention only a few.

As reported by Mayenne[74], Vinberg[117], Stroganov[104] and Uhlmann[108] the first "sewage ponds" in the modern sense of the term are based on an idea of Stroganov[104] in the Russia of his day. Thus from 1919 to 1927 the sewage ponds of Lublino and Luberzi, which received the sewage of the city of Moscow, operated very successfully. The sewage was purified at a rate of 124 to 250 $m^3 \cdot d$ in ponds of approximately 250 hectares area. (See Figure 1, sketch, "sewage ponds of Lublino and Luberzi near Moscow"). The pond systems of the cities of Minsk and Soligorsk are still working satisfactorily, so that Vinberg[117] comes to the conclusion that the sewage pond method should be applied more than ever in the Soviet Union.

In the Socialist states reports have been issued on the sewage pond method principally by Vinberg[117] Macuch[70], Swiatchowska[105] and Pytlik[92].

The sewage purification effect in still water was discovered purely by chance in the U.S.A. at about the same time as in Russia and the first sewage ponds were constructed as "secondary or supplementary purification systems" in the western and southwestern parts of the United States of America so that thereafter the sewage could be used hygienically without hesitation for agricultural purposes[90,80]. At this time a few sewage ponds, still operating inadequately, were put into operation in Palestine and investigated and the results constituted the basis for the construction of sewage ponds in Texas[20]. Ponds were built in Fessende, North Dakota, in 1928, and it is reported by Porges[90] that they still purify the sewage hygienically and satisfactorily today.

As reported by Wennström[114] a number of shallow ponds in Lund (Sweden) have been operating since 1934. They receive household sewage and have a high purification rate.

The first so-called "stabilization ponds", i.e. ponds which receive raw sewage preferably not prepurified mechanically, were planned and constructed in North Dakota in 1948[41] with subscriber capacities of 500 to 1000 inhabitants per hectare. Accurate planning principles for this type of pond were worked out at that time and are still of fundamental importance today.

After 1945 the sewage pond method was discussed particularly in English language literature. Well-known research workers writing on the sewage pond method included Fitzgerald et al.[24,25], Gotaas et al.[30-33], Oswald [80-85], Porges[89], Parker et al.[87], Palmer[86], Putzmann[91], Van Heuvelen et al.[41], Van Eck[111], Collom[14], Hicks[42], Allen[2], Krauss[62] Caldwell[10], Gloyna et al.[28], Hermann et al.[40], Wennström[114], Williams[116], Wisniewski[118] and [130].

In the United States of America the sewage pond method has been widely developed. As shown by a statistical survey of 1957[134], the number of these purification systems increased from 1945 to 1957 from 45 to 631. In comparison with other types of purification systems being constructed, sewage ponds at present show the greatest percentage increase. A census taken recently in the U.S.A.[131] shows that a total of 1,647 ponds are being used successfully in 41 states and purify the sewage for 4,285,036 inhabitants.

Porges[90] reports that sewage ponds are particularly well suited for small communities. They are being constructed by the municipal authorities in increasing numbers, but their importance for larger cities should also not be underestimated, and Porges finds that the spread of the pond method is "phenomenal" and that sewage pond purification methods have a great future.

Sewage pond are also proliferating more and more in Canada, which has the largest pond systems in the world. The city of Regina, for example, with about 100,000 inhabitants, is making great efforts to do away with the present inadequate clarification installations and to replace these by sewage ponds, which will cover approximately 1020 hectares of area with an average depth of 1.0 m; the pond system will cost 4.5 million dollars and will represent a saving of 1.8 million over a traditional type of clarification plant[131].

Sewage ponds from largest cities down to very small communities that are already operating well are described by Parker et al.[84], Malchow-Moller et al.[73], Wennström[114], Collom[14], Allais[1], Oswald[80], Vinberg[117], Pytlik[92], Van Eck[111], Gaillard et al.[26,136].

Parker et al.[87] describe the pond systems of Werrebie near Melbourne, which have been operating since 1940/41 and which purify the sewage from the city of Melbourne 39 km away, and Collom[14] gives a very detailed account of the pond system of Auckland, New Zealand, which was put into operation in 1960. (See Figures 2 and 3, pond system of the City of Auckland).

Malchow-Moller et al.[73] give a detailed account of the oxidation ponds of Fuglebjerg in Denmark. The pond system receives a charge of 150 m^3 of sewage daily (about 1000 subscribers) and has an effective area of approximately 2375 m^2.

The sewage pond method is also becoming important in France. Allais[1] writes that besides the large sewage pond of the City of Strassburg, ponds will be constructed for smaller communities in the years to come.

In Germany, among other authors Imhoff[47], Uhlman[108-110] and Liebmann[66] have dealt with the oxidation pond method. In East Germany Knabe[57-60], Zunk[123,124], Knaach[56] and the present author[99] support the purification in sewage ponds of household waste in rural communities.

The sewage ponds operating in East Germany should also be checked for their efficiency. At the same time economically feasible possibilities of exploiting the sewage purified biologically in the ponds should also be considered. Furthermore, increasing numbers of ponds with relatively small surface area per subscriber should be constructed and investigated systematically.

When we consider the number of subscribers per hectare of pond surface in Table II from this point of view, we find that under natural conditions in the German Democratic Republic the size of pond surface of at present 4 to 5 m^2/EGW is comparatively small compared with the international scales, nevertheless there are technical possibilities of making the biological processes in the sewage pond just as effective while reducing the pond area per subscriber. The possibilities of intensifying the biological processes in the sewage pond are also emphasized by Oswald(80,81), Keese(52) and Krauss(62). Figures 4 and 5 illustrate an algal reaction pond recently developed by Professor Oswald, which is characterized by intensive biological processes.

2.2.2 Mode of operation

The sewage purification effect in ponds depends on the "symbiotic" bacterial and algal activity, which entails physical, chemical and biological action. In contrast to traditional biological purification methods, the oxygen requirement in the natural, biological sewage pond method is furnished by the photosynthetic activity of the pond algae (and/or) the atmospheric oxygen contribution (and/or) the additional oxygen supplied with the water of dilution (especially in sewage fish ponds). The most important physical factors affecting the organisms in the sewage pond are light, temperature, and the specific weight of the sewage components. The hydrostatic pressure, of course, is of importance for any microbial life prevailing in the pond(19), but in the shallow ponds used for sewage purification this can be neglected. The light has a decisive effect on the photosynthetic performance of the pond algae, since by energy relationships carbon dioxide and water are assimilated to glucose, liberating oxygen. The following process takes place

$$6CO_2 + 6H_2O + 675\ \text{kcal} \rightleftharpoons C_6H_{12}O_6 + 6O_2$$

Actually this biochemical process is somewhat more complex and takes place in two stages, e.g. via phosphoroglyceric acid, adenosine-diphosphate, among others, as is evident from Figure 6 and 7(12,62). It may be stated that the biochemical processes in the sewage pond depend not only on the ambiant temperature and the nutrient quality of the sewage, but primarily on the penetration and intensity of the light in the euphotic zone. The penetration of the light, in turn, is directly proportional to the intensity of the light and inversely proportional to the frequency and composition of the algae cells. If it is desired to secure a high utilization of the radiant energy in the treatment of the sewage, then depth and volume of the pond must be considered in correct relation to each other (1 : 1). The pond must be kept shallow, of course, so that sufficient light can be absorbed, since otherwise the density of algae will decrease and the sewage cannot consume sufficient oxygen. The useful average depth in centimetres, therefore, should not be more than 1.00 m under our climatic conditions.

The correct ratio of pond surface to pond volume is also very important for full biological purification of the sewage (faeces). To calculate this volume for a given temperature, Herrmann and Gloyna[40] have presented the following equation:

$$V = 25 \cdot 10^{-5} \cdot N \cdot q \cdot y \ (1{,}072)^{(35-T)\ 3)}. \qquad *$$

This can be employed in calculating the sewage pond volume.

The oxygen contents of the pond water may be rapidly increased by intensified biological activity of the algae, so that the soil substances can be completely broken down aerobically. Gotas[33] finds an oxygen increase due to algal activity of up to 28 $g/m^3 \cdot d$, while the atmospheric oxygen contribution in the pond is only about 5 $g/m^3 \cdot d$. The bactericidal effect of the algae, which is said to be caused by the so-called "chlorellin" [21,42,71], is also remarkable.

The oxygen of assimilation reverts in winter to its normal volume. If there is an ice cover with snow on top, the euphotic zone is also somewhat decreased. At the same time the biological processes are retarded in accordance with the RGT rule; a change over of the sewage pond from the aerobic to the anaerobic phase is then possible[1].

Figure 8 shows the relation between dependence on temperature and rate of decomposition constructed by Hermann and Gloyna[40] in this connection. It is applied to the calculation of the time the sewage phase in stabilization ponds according to experience with the sludge digestion, on the basis of the Van't Hoff-Arrhenius equation. The following relation is obtained

$$\frac{t}{to} = e^{c(T_0 - T)} \ ,$$

---

* V = volume (m^3), N = number of subscribers for pond loading factor, q = amount of sewage accumulating per individual or animal and per day in litre, Y = average BOD_5 of inflowing sewage (faeces after dilution), T = average annual temperature.

where t is the reaction time at a given temperature T, t_o is the reaction time at the temperature T_o and c is a temperature constant with the value 0.0693. For e^c the value 1.072 is given. In Figure 8 the retention time t_o is taken to be 5 days; the detention time t is to be determined for a principal temperature T_o of 30°C at an assumed temperature T of 35°C or 5°C. After calculation with the aid of the above equation detention times of the sewage in the ponds obtained at a temperature of T 35°C are t 3.5 days at a temperature of T 5°C, t = 28.3 days.

If the average summer temperature is T_o = 30°C and the retention time t = 20 days, then for 1. T 25°C and 2. T 5°C the following retention times t are obtained:

1. $$\frac{t}{20} = 1{,}072^{(20-25)} = 14 \text{ days,}$$

2. $$\frac{t}{20} = 1{,}072^{(20-5)} = 57 \text{ days.}$$

Hence the decomposition effect in summer is considerably greater than in winter.

Actually, under our climatic conditions good breakdown effects are obtained in oxidation ponds both in summer and in winter for a given sewage detention time, since as the temperatures fall slowly, the aerobic micro-organisms are capable of "adapting"[109]. The temperature-time relationships, therefore, are important for the operation of oxidation ponds, but for anaerobic preliminary clarification tanks and anaerobically operating manure lagoons they are entirely applicable.

Every microorganism in the pond has become adjusted to a certain temperature range, in which it is best able to carry out its activity. If the ambiant temperature suddenly goes above or below the temperature optimum, reduced metabolism processes are the results. The temperatures of pond water which may vary between + 5°C and + 20°C in general correspond to the conditions of the sewage organisms.

The hydrogen ion concentration of the pond water also influences the composition and activity of the microorganisms. Sudden pH changes have an unfavourable effect on the activity of the bacteria and algae. During periods of high light intensity the pond algae consume a great deal of carbon dioxide, at a faster rate, indeed, than it is produced. The pH value can then go as high as 11. Most of the heterotrophic organisms prefer pH ranges between 6 and 9, the favourable values lie between 7 and 8. Although the autotrophic organisms will withstand greater fluctuations than the heterotrophic, nevertheless a high pH value inhibits the concentration in the pond water[19]. Another disadvantage of a high pH value consists in the possibility of precipitation of calcium sulphates. Phosphorus, however, is a basic food element of the sewage algae, and therefore every deficiency of this element retards the growth of algae.

The algae of the sewage pond developed best at pH values of 7 to 9.5.

Uhlmann[110] deals thoroughly with the three stages of breakdown of the organic sewage components, describing the first stage of bacteria and colourless flagellates, the second of chlorococcal green algae and coloured flagellates, and the third stage of protozoa and metazoa which consume algae and detritus. In the first stage of purification anaerobic bacteria effect the bacterial breakdown on the sludge layer at the bottom of the pond[73,87,108,109], while in the second stage Chlorella pyrenoidosa, Cryptomonas ovata, Chroomonas caudata, Chlamydomonas variabilis, etc., are mainly active[86,110]. In this sewage pond, oxidation pond I, aerobic conditions with vigorous algal activity prevails. In oxidation pond II we find such filterers as Daphnia magna, Branchionus urceolaris, etc.[110]. The Daphniae are often occupied with Colacium cyclopicola and with Petritrichae (Rhabdostyla and Carchersium varieties), which intensify the filtering effect and thus bring the sewage to the clear water stage, i.e. render it hygienically satisfactory and virtually sterile.

In the oxidation pond chironomidae larvae (Chironomus thummi, Chironomus plumosus) are often present.

Figure 9 shows some of the algae occurring in the sewage pond, the quantities and percentages of which, of course, can vary greatly from pond to pond.

For the optimum development of sewage organisms, therefore energy sources, optimum temperatures, greater quantities of nutrients (C, O, P, N, H, K, S), trace elements (Fe, Ca, Zn, Cu, Mg, Co, Br) and specific organic substances are required.

Nitrates, nitrites, sulfates and carbonates are broken down in the oxidation reduction reaction[19]. This process is always associated with the decomposition of organic sewage substance. The reduced forms of the nitrogenous and carbonagenous substances are ammonia (NH_3) and methane (CH_4). These gases originate entirely from the anaerobic decomposition; similarly, the reduced forms of the organically bound sulphate, namely hydrogen sulphide and similar chemical compounds. They are often limiting factors for the aerobic breakdown of the sewage substances, and therefore undesirable.

Figure 10 illustrates the good purification effect of the Greifswald-Ladebow[99] installation, and present a picture of the illumination of nutrient substance and BOD_5 reduction in the various purification stages.

2.3 Variants of sewage ponds for the purification of sewage in rural communities

From the section on "Definition of terms" it is evident that there are many different possibilities for the application of the sewage process to the purification of organically soiled sewage from rural settlement. The logical utilization of the biologically purified sewage also has an importance that should not be underestimated. Therefore, every effort should be made to exploit local conditions for these purposes. Figure 11 shows a few different possibilities of hygienically satisfactory and economically advantageous sewage treatment and utilization, which could serve as a basis for discussion in many rural communities of East Germany.[60]

2.3.1 Oxidation-sewage fish pond system, with specific attention to the installation at Bandelin by Greifswald

2.3.1.1 Oxidation pond system

The community of Bandelin has a central drinking water supply, but sewage purification has thus far been carried out in a three-chamber clarification plant. According to the bacteriological and chemical tests, the "purified" sewage is "very doubtful" from the hygienic point of view. The park pond installations there, are thus at present being modified in accordance with suggestions of the Hygiene Institute, Chair for Rural Hygiene, so that the sewage can first be purified in a number of ponds and then utilized by carp in sewage fish ponds (see Figures 12 and 13).

The sewage enters the main collector for the mechanical three-chamber clarification plant. From here, after at least 1 1/2 hours settlement time, it can be pumped to oxidation pond I. The input to this pond is at the bottom of the pond rather than at the surface, since the warmer sewage waters will then be able to come to the surface slowly and mix evenly with the waters already present in the pond[99]. From oxidation pond I the sewage can pass to oxidation pond II and finally to oxidation pond III. To this pond system are added three sewage fish ponds with a total area of 0.86 hectare. The existing park ponds are suitable for use in an oxidation-sewage fish pond system, with the reservation that owing to the extensive stands of trees around the ponds the exposure to the wind is unfavourable. The trees and bushes, preferably about the three oxidation ponds, are therefore to be cut back by as much as 10 metres from the pond boundaries, preferably around the three oxidation ponds and on the two islands planned in these.

The area of the oxidation pond system is 0.44 ha. Oxidation pond I will operate primarily as an "algal" pond in which oxygen is produced for the aerobic decomposition of the sewage materials under the influence of a vigorous algal activity. The oxidation ponds II and III can be termed "Daphniae", in which the filterers must convert the sewage into the clear water stage so that it is fully hygienic and can be fed to the sewage fish ponds.

Table III illustrates the action of a number of oxidation ponds and gives information on the hygienic reliability of the pond method. Table III was made up on the basis of literature data and the author's own results[99].

Oxidation pond III and the sewage fish ponds can be fed fresh water as desired through a diversion channel.

The mean depths of the oxidation pond is Zm = 1.00 m, and the depth of the sewage fish pond is also Zm = 1.00 m. Any desired water level can be maintained by means of sluices. The level should vary in the oxidation ponds in the euphotic zone, but should not substantially exceed 1.0 m.

The biologically purified sewage for fish rearing use can be let out through a drain mechanism (bottom drain in the form of a sluice) into the receiving water ditch, which then conducts the water into the Peene.

Assuming a daily sewage accumulation of 100 litres per inhabitant and an hourly inflow of Q 10 of the daily sewage quantity, then for 350 EGW connected, we may expect the following input of sewage into the mechanical clarification system:

Q = 350 · 100 = 35,00 3/d
+ 100% allowance
(rain and ground water) = 35.00 m^3/d
= 70.00 m^3/d = 7.00 m^3/h

Since the clarification plant has a useful volume of 18.00 m^3, we get a

$$\text{Throughput times } h = \frac{\text{deposition space } (m^3)}{\text{quantity of water } (m^3/h)}$$

$$h = \frac{18.00}{7.00}$$

$$h = \underline{2.6}$$

The retention time of 2.6 hours in the mechanical clarification apparatus is sufficient to reduce the BOD_5 of the sewage from approximately 54 g to at least 35 g/E · d, when we recall that according to Imhoff[48] only 1.5 hours were required for this purpose.

For the breakdown performance of the oxidation pond the following calculations are obtained:

Total subscriptions = 350 EGW, the mechanically pretreated sewage is taken as 35 g/E · d.

Possible surface load of oxidation pond:

3 to $5\ m^2/EGW$[48,97].

The total oxidation pond area is about 0.44 ha; in accordance with the natural conditions it was divided into three oxidation ponds, namely:

Pond I with an area of 0.12 ha

Oxidation Pond II with an area of 0.08 ha

Oxidation Pond III with an area of 0.24 ha

Total 0.44 ha

The oxidation ponds are charged as follows:

$4400\ m^2/350\ EGW = 12.5\ m^2/EGW$

Possible surface charge of the oxidation pond

$4400\ m^2/1500\ EGW = 3\ m^2/EGW$

The total BOD_5 at 350 EGW and 35 g/E · d is:

$350\ EGW \cdot 35\ g/E \cdot d = 12\ 250\ g\ BOD_5 \cdot d$

The breakdown performance of the oxidation ponds is calculated for a total content of

$$4400\ m^2 \cdot 1.00\ m\ \text{depth} = 4400\ m^3$$

$$= \frac{12\ 250\ g\ BOD_5 \cdot d}{4400\ m^3}$$

as $2.8\ g\ BOD_5/m^3 \cdot d$, i.e. a charge of approximately $2.8\ g\ BOD_5/m^3$ sewage (very lightly loaded oxidation ponds).

Possible charges for oxidation ponds is 9 to 18 g BOD_5/m^3 ponds of content and higher[97,109].

The retention time of the sewage in the oxidation pond is:

Sewage input rate $= 70\ m^3/d$

Pond volume $= 4400\ m^3$

$$\frac{4400\ m^3}{70\ m^3/d} = 63\ d^*$$

The calculated retention time in oxidation ponds comes to a total of 63 days; however, a retention of about 30 days is sufficient for a sewage purification.

2.3.1.2 Sewage fish ponds

2.3.1.2.1 General Remarks

The biological purification of mechanically purified domestic sewage in fish ponds goes back to an idea of Professor Hofer, who had the first test systems constructed in the year 1911 in Strassburg.

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* Input and evaporation ± 0.

In addition to these ponds, which received 1/35 of the total sewage of the City of Strassburg, partial systems were then built in Bergedorf near Hamburg, Feucht near Nürnberg, Amberg and Grafenwöhr in Bavaria, Allach near Munich, and finally the largest installation of this kind in Ismaning in the northeast part of the City of Munich. Other ponds are mentioned by Professor Demoll at the end of his Handbuch der Binnenfischerei Mitteleuropas, which was published in 1926. More recent information will be found in Professor Liebmann's Handbuch der Frischwasser- und Abwasserbiologie, Band II, 1960.

The most important prerequisite for the thriving of fish in sewage fish ponds is an adequate supply of oxygen. While Imhoff(48) states that the supply must not fall below 3 mg/litres of oxygen, Reichen-Bach-Klinke(94) recommends at least 4 mg/litres. Accordingly, unlike regular sewage ponds, sewage fish ponds must basically receive inflows of water of dilution so that the oxygen content of the water does not fall below Imhoff minimum of 3 mg/litres. Otherwise, fish may be expected to die.

Whether sewage fish ponds will work well or not can be determined by physico-chemical and bacteriological investigations. In most cases ammonium, nitrates and phosphates are eliminated from the sewage; there must, of course, be vigorous phytoplankton development in the pond(94).

BOD_5 decreases and germ count reductions can also be detected, as the author succeeded in determining(99) (see Figure 14).

2.3.1.2.2 Bandelin sewage fish ponds

1. Management

Provided the sewage fish ponds are preceded by oxidation ponds and the possibility is afforded of introducing water of dilution into the fish ponds through the diversion channels, then the oxygen supply is looked after with a double safety factor, since the water draining from the oxidation pond will have normal oxygen content and constitutes only a slight sewage load in the fish pond. The particular soil matters present in the sewage are deposited ponds where for the most part they are mineralized. The water to be introduced from the oxidation ponds into the fish ponds should be diluted in a ratio of 1 : 3 to 4 with receiving water coming through the diversion channels.

From the hydrographical drainage area of approximately 1 km² we can calculate an available water supply of 5 litres per second midway between high and low water, a low water supply of one litre per second and a winter high water supply of 60 litres per second.

Drainage from the oxidation ponds takes place on the average at a rate of 1.25 litres/second, so that sufficient water of dilution is available.

The three sewage fish ponds have a total area of 0.86 ha. Fish are to be kept in the pond only in summer. The ponds should be used as rearing ponds for carp, which develop very well in sewage fish ponds. Two year old carp (200 to 250 p)* are introduced into the fish pond, which have already been charged with fresh water, between the end of April to the middle of May.

The occupation density and fish yield depend, according to Kreuz[63], essentially on the kind of soil, the state of cultivation of the soil, the quantity and quality of the original water and the water added, the position of the pond and the climatic conditions. The population calculation can be carried out by Kreuz's formula[63].

$$b = \frac{T \cdot H}{a - c} + v = \frac{Z}{z} + v ,$$

where:

b = fish census,

T = weight increase in kp/ha,

H = pond area in ha,

a = desired final weight o. fish in kg,

c = initial weight per fish in kp,

v = allowance for individual fish loss in % (two-year carp, 5%),

Z = total weight increase of fish in pond, kp/ha,

z = weight increase per fish in kp.

Assuming a first-class yield (320 kp/ha increase of weight), a pond of area 0.86 ha, an input weight per fish or 250 p and an expected increase per fish of Ø = 1000 p, we get the following calculation:

First class yields:

$$b = \frac{320 \cdot 0{,}86}{1{,}25 - 0{,}25} + 5\,\% = \frac{275{,}20}{1{,}00} + 5\,\% = 275{,}20 + 13{,}75$$
$$\widehat{=} 289\ K_2$$

A first class yield can be expected in the sewage fish ponds in question. In spring, therefore, 289 fish are to be put into the pond, and may be taken out in autumn of the same year at a weight of 1250 to 1300 p per fish in the autumn of the same year. If it is found on taking out the fish in autumn, that the proper census number was not used, corrections should be made the following year when putting the two-year old fish in again, so that the desired weight increase can be obtained. There is no feeding of the carp

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* Translator's note: Presumably a "pond" = 1/2 kg.

in the sewage fish ponds, because the nutritious sewage from the oxidation ponds produces enough natural food to ensure a good increase in the weight of the carp.

Since carp thrives best at temperatures about + 20^{o}C, the fish ponds were planned so that they did not exceed a maximum depth of 1.50 m, ensuring rapid and uniform heating of the water.

In autumn the fish ponds should be drained and the fish removed. However, from 2 to 3 weeks before that all the carps should be transferred to sewage fish pond III, because here no further sewage soil materials can be detected, and thus there will be nothing to impair the taste of the fish.

Whereas in traditional sewage fish pond systems the biological purification of the sewage in winter, must be undertaken, in some other way after drainage of the pond, here the sewage purification process can continue to be carried out in the oxidation ponds, and the purified sewage allowed to flow into the fish pond ditches, which at the same time have to drain the fish ponds during the period when they are not in use, through the drainage system to the receiver ditches 39.

The annual liming of the pond soil should be done with quicklime (CaO) or carbonate of lime ($CaCO_3$). The quicklime can be spread at a rate of 300 to 400 kp/ha, or the carbonates at a rate of 600 to 800 kp/ha. Liming is very important both in combatting pests and parasites and for the full utilization of the nutrient substances accompanying the sewage. Owing to the caustic effects of quicklime, which last 2 to 3 weeks after liming, the pond bottom is effectively disinfected. Hence after drainage of the pond and removal of the fish preferably the parts in front of the sluice gates and any puddles left behind should be treated with it. The most favourable lime content corresponds to a hydrochloric acid fixing capacity (SBV) of 2 to 5. Enough lime must therefore be added to the ponds so that SBV of 2 $cm^3 HCl/100m^3$ water is attained.

It is obvious that after removal of the fish a record should be made of the fish yield, census, etc., because proper conclusions for the correct management of the ponds in future years can only be obtained from the comparison of these figures. Table IV shows a suggestion for the registration of the most important factors in simplified form.

2. Fish diseases

If dead fish are found in the ponds, or if the fish show an abnormal appearance or behaviour, there is a suspicion that a fish disease is present.

Regulations already exist[137,138] indicating what those authorized to rear fish must consider at the appearance of fish diseases. The first regulation of 7.12.1959, for example, reads: "Deaths of fish must be reported immediately to the District Council by holders of commercial fisheries licences. The same holds for the holders of angler's licences. To determine the causes of death, the parties concerned should send water samples and fish corpses immediately to the Institute of Fisheries of the German Academy of Agricultural Sciences at Berlin, unless the District Council itself carries out investigations. If the death of the fish is due to sewage, the District Council must report this to the pertinent hydrographic authorities".

The most dangerous disease in connection with carp pond management is infectious oedema (carriers: bacterium pseudomonas punctata and bacterium pseudomonas fluorescens), which, although it can be successfully combatted with antibiotics, still occurs frequently. The disease is reconizable from the bloated body (accumulation of fluid) and from ulcers in the skin and muscle tissues of the fish.

The mixing of fish stocks in the pond should be avoided, because this disturbs the so-called "epidemic biological equilibrium" and may then favour the outbreak of oedema. Therefore, the young fish required annually (for the Bandelin pond system approximately 300 two-year old) should always be obtained from the same fish hatchery.

In order to prevent the occurrence of disease the carp are injected with chlornitrine or are bathed in a chlornitrine solution. 3 mg chlornitrine is injected into each of the two-year old fish. This procedure and other similar ones do not come, of course, in part permanent immunity. At a later time, therefore, there is every possibility of the carp becoming infected in a contaminated pond.

Another disease to be noted is gill blithe, which can occur in the summer months at water temperatures above 20°C in ponds charged with sewage. (Carriers:) filamentous fungus branchiomyces, plugging of the gill blood vessels.)

Gill blithe can be effectively reduced by additions of fresh water and doses of 200 kp/ha quicklime. Infecticus skin discoloration, gravel and gill worm can also occur, but can be kept in check by proper management of the ponds.

2.3.2 Oxidation ponds system from the example of the Kemnitz by Greifswald system

At the suggestion of the Hygiene Institute of the Ernst-Moritz-Arndt-University, Greifswald, Chair for Rural Hygiene, and the District Hygiene Institute at Greifswald, an oxidation pond system was planned for the LPG Rappenhagen and was built by the "Westliche Ziese" Improvement Association (see Figure 15, plan and section of the oxidation pond system).

This system purifies the sewage from a social centre and administration building with a total of 25 EGW. It was planned for a capacity of 50 EGW, since in a short time an additional 25 EGW are to be put on to the system. The pond system is situated to the south of the building, about 100 m away, and comprises two mechanical settlement installations, oxidation pond I and oxidation pond II (see control sketch of the "settlement systems", Fig. 16 and 17).

The mechanical settlement tanks were dimensioned so that they would have to be desludged only once or twice a year. They serve, at the same time, as digestion chambers, in which the anaerobic processes take place; settlement tank I, however, is also used simultaneously as a grease separator.

For oxidation pond I, a mean pond bottom area of $8 \cdot 10$ m = 80 m^2 was planned, and for oxidation pond II, an area of $8 \cdot 15$ m = 120 m^2. The first pond is divided into four individual cells by polyvinylchloride foil partitions 0.80 m high with a wall thickness of 1 mm, in which the sewage is purified in stages biologically, biochemically and physically. This division also permits a favourable mixing of the sewage coming from the mechanical settlement plant 2 at a level of 0.20 m above the pond bottom.

The mean water depth Zm is 0.60 m, the maximum water level Z_{max}, 0.80 m.

Oxidation pond II is intended merely for final clarification. The biologically purified sewage flows over a drain structure (bottom drain) in a free fall into the drain pipe to the receiver ditch.

2.3.3 Hygienically satisfactory purification of sewage from barns

2.3.3.1 Preparation of animal manure

With the continuous intensification and concentration of agricultural production manure lagoons are becoming more and more important. They make it possible to apply industrial production methods in agriculture, especially animal production, since the sewage from barns and manure can be hygienically processed in a satisfactory way with the aid of manure lagoons. A pig breeding farm may have 4,000 pigs or more, so that in conjunction with water carrier manure removal, more rapid accumulation of faeces can produce hygienically doubtful conditions. By combining water carrier manure removal with the manure pond, therefore, a labour saving, hygienically reliable and economically satisfactory solution can be procured.

Manure lagoons, however, may also be important for poultry farms, and to some extent for beef cattle and dairy cattle establishments[133]. They are extremely important, however, for pig breeding establishments, since here the faeces accumulate in large quantities and rot very rapidly, and then strongly favour the development of disease-carrying insects. For example house flies like to lay their eggs in pig manure, and in North Germany they may raise up to six generations of flies in a single summer, which may then become noticeable around the pig manure pile in a radius of 20 km.

These flies frequently carry disease instigators, because the latter remain virulent in the rotting manure for a month or more. The cholera Vibrions, for example, live 20 to 30 days. Tuberculosis and typhus bacteria are extremely resistant to rotting and frequently remain viable for 6 months. The carriers of spinal poliomyelitis live for three months in rotting substrates, while the viruses of foot-and-mouth disease in ruminants can survive 3 to 3 1/2 months in this faecal matter. The swine-pest virus can also stay alive for months.

The hygienically satisfactory treatment and economically logical utilization of faecal matter and barn drainage, therefore, should be of equal concern to hygienists, farmers, veterinary hygienists and hydrologists.

In most cases the pig dung from the manure collectors is conducted along with the liquid manure and other barn drainage waters into closed collecting ditches, and the nutritious mixture of liquid and solid manure can be taken by manure carts at any time for additional fertilizer and for other agricultural use. Unfortunately the leading directors of farms often underestimate the nutritive values of the pig manure, although it contains up to 1% nitrogen and 0.6% phosphoric acid. Consequently, collecting ditches often overflow and create unhygienic conditions.

In this connection we may mention the danger of possible groundwater contamination, especially with nitrates, by leaky collecting ditches.

There are many problems which can be solved by Doctor Rohde's method of composting pig manure[99]. It is a very simple method and any farm can apply it. The pig manure is spread in beds 4 m wide, 0.40 m high and of any length. In dry weather it is turned over with the plough once a week, and in summer 2 to 4 times a week. The water content of the manure decreases quickly after a short time, owing to mould formation. The manure thus prepared can now be transferred to stacks 3 m wide and 1.2 m high, which heat up 50 - 60°C.

Horizontal ventilation channels should be provided on the grounds, as well as vertical ones, so that pig manure will rot more quickly and more uniformly. In agricultural practice, unfortunately, this method has not become very common, because the necessary AK consumption for proper execution of the composting keeps many farmers from applying it.

In some piggeries of the Czechoslovakian SSR, the so-called "separator" is being applied experimentally first. This device separates the manure and urine by the press method, leaving a relatively dry manure for subsequent composting. Similarly, in a number of capitalist countries so-called "automatic presses" are used to produce briquettes of various size and shape. These briquettes also turn mouldy after a short time and show high organic and inorganic component contents which can be used to increase soil fertility.

The liquid manures accumulating in the pig barn along with other drain water from the barn are conducted in our farms to liquid manure ditches, as already mentioned, then mechanical clarification plants and finally to a relatively large receiver. Only in isolated instances, therefore, do we have satisfactory biologically purified barn drainage which can be utilized agriculturally or can be fed to the receiver ditches. It is essential, however, that effective purification systems gradually be instituted here also. One possibility is afforded by the method described in what follows for purifying barn drainage in manure lagoons, which was developed about 1960 in the U.S.A. and Canada and is now being applied there successfully.

2.3.3.2 Problems in planning and designing manure lagoons

In planning and designing manure lagoons a correct selection of location is of extreme importance. From the many factors which must be considered in the designing of ordinary sewage ponds, we may single out the following[99]:

1. The proportion of soil substance seeping way. If the soil is permeable, this proportion must be taken into account accurately. In the case of permeable soils, means of sealing the bottom of the pond must be employed, since otherwise the functioning of the ponds may suffer. Clay, loam, polyethylene and similar chemical compounds make suitable sealers. The proportion of sewage lost through seepage and evaporation may be put at 1 litre/s · hectares.

2. Possible contamination of the ground water. Besides the danger of infecting the ground water, nitrates and tensides may get washed into the well, so that in the installation of a pond system the geological conditions must have been carefully investigated.

3. The utilization of the natural terrain for pond construction. Suitable ponds, puddles, or depressions, should be properly utilized for this purpose. At the same time consideration must be given, among other things,

to the supply of fresh water from a receiver.

4. The prevailing wind direction and distance from built-up areas. During a few days in spring and autumn the manure pond may give off offensive odours. On the other hand, a certain exposure to the wind is desirable (access to atmospheric oxygen).

5. The shape of the ponds. Oval and round ponds are more reliable in operation than rectangular and square ones, since they do not allow any undesirable "dead zones" to form (depending on the number and form of input and drainage structures).

6. The possibility of fresh water and sewage extraction. In the system of manure lagoons, the possibility of favourable points for water extraction in order to mix purified sewage from the manure lagoons fresh water for subsequent agricultural utilization should be considered.

7. Accessibility of the pond area to vehicles. Since manure lagoons, expecially lagoon I, must under certain circumstances be abandoned after a few years, access routes acquire special importance.

The purification of barn drainage and the introduction of solid animal faeces into manure lagoons with a view to decomposing the organic substance has not yet been tried in East Germany. Nevertheless there are systems into which household and barn sewage are introduced together (Christgrün). In Neuruppin district, for example, there is a manure lagoon which receives the sewage from the cattle state farm LPG Manker; there are no manure lagoons intended exclusively for the rotting of manure-urine mixtures from piggeries in other European countries, as yet.

Manure lagoons have been increasingly successful in the last three years in the U.S.A., and in roughly the last four years in Canada[7,45,130]. They are not, to be sure, a cure-all, but are highly prized as a reliable means of "purifying liquid and solid manure".

For the planning of manure lagoons, figures comparing the accumulation of the various animal faeces with household sewage are indispensable. This problem was first discussed in connection with the planning of the manure lagoons in 1962 in the U.S.A. by Henderson and Saunderson[39]. They showed, among other things, that the correct carbon/nitrogen ratio is vital for the decomposition process in the manure lagoon. On the basis of a human being weighing 75 kp and consuming a normal amount of food daily, the equivalence compared with various domestic animals are shown in Table V.

The figures of the table give values which ensure complete oxidation of the organic substrates, assuming that fresh sewage or manure-urine mixture is introduced into the manure lagoon. Although these figures cannot be applied directly to German conditions, nevertheless they do give indications of the load values of individual types of animal. Such investigations have not hitherto been undertaken in East Germany, although principles have been worked out on the accumulation of animal faeces, which are important in dimensioning the pond surfaces[99].

Manure lagoons for East Germany, which should preferably be operated with mechanically clarified barn sewage, should be given surface areas of 1.25 m^2 to 2.50 m^2/pig, or 0.50 to 1.50 m^2 per cow.

To calculate the decomposition action of manure lagoons the analytic and population equivalence given in Table VI, after Leuthier[65], can be used.

In Table VII we show the results of investigations of sewage from the Andershof/Stralsund piggery.

The sewage specimens were prepared under laboratory conditions, which explain the temperature rise. Essentially, no elimination of nutrient substance takes place. The BOD_5 reductions, however, average 64%, i.e. the sewage from the Andershof/Stralsund piggery, after remaining about 4 days in the anaerobic pond, has only approximately twice the BOD_5 quantities of household sewage. The remaining sewage nutrients are then eliminated very rapidly in the subsequent aerobic cells (cf. also Eby[19]).

It is proposed to apply the manure lagoon method in a number of agricultural establishments, e.g. VEB Mast- und Schlachtvieh der Stadt Greifswald, VEB Mast- und Schlachtvieh Andershof/Stralsund and in VEG Wolgast. The pond surfaces are to dimensioned according to 1.25 m^2 to 2.50 m^2 per pig. The mean useful water depth will not exceed Zm 1.20 m, since otherwise the anaerobic phases of the decomposition of organic substrates are too greatly expanded and may result in the generation of unpleasant odours (see Figure 18 pond lagoon system Andershof/Stralsund). In VEB Mast- und Schlachtvieh Griefswald some of the sewage processed in oxidation pond III is to be used again as water for flushing down the pig droppings, since insufficient fresh water is available. In planning the manure lagoon system for VEG Wolgast it is projected that the biologically purified sewage will be sprayed with water from the Ziese receiver onto agriculturally used areas. In planning the manure lagoon system in the Andershof/Stralsund piggery consideration was also given to reusing the purified water draining from pond IV for flushing purposes. This sewage water can be chlorinated as required.

2.4 Classification of sewage ponds in East Germany with respect to types of ponds

The sewage ponds used to date in East Germany can be classified in accordance with the terminology already presented as oxidation ponds, stabilization ponds and sewage fish ponds. Which type will be chosen depends essentially on local conditions and economic considerations. Whereas in the oxidation pond method a mechanical or partially biological (partial biological systems and anaerobic preliminary settling tanks) pre-treatment of the sewage must be undertaken, this need not be the case where stabilization ponds are employed. The nature of the pre-treatment of sewage, therefore, can be an essential aspect in classification according to principal types of ponds. Obviously, the nature and quality (chemical composition) of the sewage, among other things, must be taken into account. The type of pond projected for sewage purification also determines the effectiveness of the purification process that may be expected. In stabilization ponds, for example, the BOD_5 decomposition is between 60 and 70%, whereas in the case of oxidation ponds it lies between 90 and 100%.

The main types of pond described here and after by the author are described as O-, S- and F-types.

2.4.1 Oxidation ponds (O-type)

These ponds purify sewage that has been mechanically or in part biologically pretreated. The mechanical or partial biological pretreatment takes place in clarification plants (e.g. Schreiber clarification tanks or anaerobic primary settling tanks), while the biological processes are carried out in trickling filters and similar systems.

Most ponds in East Germany can be said to belong to the main type of oxidation pond. In these ponds the sewage soil substances are decomposed aerobically. In summer months the discharge from the ponds is green, yellow or colourless. There is no unpleasant odour; hence no immediate oxygen requirement is detectable. The most important characteristics of oxidation ponds are set forth in Table VIII. Here we distinguish between oxidation ponds where there is mechanical pre-treatment (e.g. Dingelstedt system) or where there is partial biological pretreatment (e.g. Blankenfelde system), or the oxidation ponds are combined with downstream drainage-seepage systems (e.g. Greifswald-Ladebow system), where mechanically or partially biologically pretreated sewage is treated.

2.4.2 Stabilization ponds (S-type)

Stabilization ponds process household or industrial sewage that has not been previously clarified. We shall only mention here the many applications of these ponds, especially for the purification of industrial sewage. Since anaerobic microbial processes predominate in these ponds, the processing is only partially biological. The first anaerobic ponds for the purification of sewage from food drying plants are operating in Gross-Kiesow, in the Greifswald district. Manure lagoons are at present being planned or built at the VEG Wolgast and VEB (K) Mast- Andershof/Stralsund for the hygienically satisfactory processing of the faeces from pig barns.

Table IX shows the most important characteristics for stabilization ponds.

2.4.3 Sewage fish ponds (F-type)

The sewage fish pond method of purifying and utilizing organically soiled sewage is used in East Germany mainly in the following manner:

1. As a method of purifying and utilizing sewage in ponds with the addition of fresh water, and
2. As a method of biological post-purification and utilization of sewage without appreciable addition of fresh water.

However, the two possibilities of purification and utilization demand different conditions. The first form always includes addition of fresh water, i.e. 2 to 5 times more water of dilution, so that adequate oxygen can be supplied (e.g. sewage fish pond at Halberstadt). In the second form, fresh water does not need to be provided in all seasons (under certain circumstances only during the summer months). Systems of this kind, for example, have been receiving the sewage water from the sewage fields of Berlin for more than 50 years (e.g. the Schönerlinde sewage fish ponds in Berlin). Similar possibilities for saving fresh water are provided by the application of combined oxidation and fish ponds (e.g. the planned Bandelin system, Greifswald District). A fresh water feed line should be available, so that water of dilution can be provided when required. Mechanical or partially biological prepurification of the sewage has proved favourable in sewage fish ponds operated in East Germany. The retention time of the mechanically prepurified sewage should be brief, because the sewage must enter the fish ponds in fresh form. The sewage is bright yellow. There is no appreciable generation of odours.

Table X shows a number of characteristics for sewage fish ponds.

2.5 Operation and Maintenace of Sewage Pond Systems

2.5.1 Operation

2.5.1.1 General operating principles*

In connection with sewage purification in small communities, special situations must be mentioned under which such systems must operate. Whereas in larger communities and cities trained personnel is available for the maintenance of the sewage purification systems, this is often not the case in the smaller community. The sewage works operator is responsible not only for the care of the clarification plant, but usually also for the maintenance of the sewage system as a whole in so far as this work is assigned to anyone at all. It often happens, therefore, that a correctly planned and constructed system is wrongly operated and the desired clarification effect is not obtained. Thus clarification systems for small communities should be rugged, simple in construction and easily controlled in operation, so that they require a minimum of maintenance. There requirements can be satisfied by the installation of a sewage pond system.

2.5.1.1.1 Housekeeping and sanitation in the system

All parts of the system coming into contact with water must be regularly cleaned and deposits of soil regularly removed. Surfaces and handles which are exposed to soiling in the course of operation must be regularly cleaned. Soiled implements, such as rakes, shovels, wheel barrows, etc., must be thoroughly cleaned after use. Individuals involved in the operation and maintenance of sewage ponds must pay special attention to their personal hygiene (e.g. thorough washing of hands before every meal).

2.5.1.1.2 Labour protection and industrial safety

The pertinent labour protection regulations must be carefully observed, including:

ASA01 General rules;
ASA02 Duties and privileges of employees;
ASA011 Work rooms, heating, ventilation, etc.;
ASA020 First aid and behaviour in accident cases;
ASA0144 Drainage systems;
ASA0445 Protection against infection;

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* My warmest thanks to Dipl. -Ing. Staeck, WWD Stralsund, for kindly transmitting the general operating principles (manure lagoons Andershof/ Stralsund).

ASA0616 Working in containers, pipelines, etc.;
ASA0860 Use of mobile pressure gas tanks per chlorine;
ASA0900 Inspection of electrical equipment;
ASA0904 Installation and operation of electrical systems.

The regulations on labour protection should be kept in a portfolio and should be available in the plant. All persons employed in the plant, should be thoroughly instructed in their content.

All individual sections of the system must be kept in satisfactory operating condition. Outsiders must not be allowed to enter the pond system without special permission (identification shield at the entrance). The attention of visitors must be adequately directed towards any risks of accident. Children under 10 years are not allowed to visit the system and those over 10 years may do so only in the company of adults.

2.5.1.1.3 Records of working discharge

A diary or weekly record of the working discharge should be kept, depending on the size of the system. All control measurements should be entered in this record. This includes, among others, the following items:

Date and hour of the measurement;
Weather;
Air temperature;
Water temperature;
Inflow and outflow of the clarification ditch (anaerobic ponds) in litres per second and outflow (last pond) in litres per second;
pH-values;
Colour (input, pond I, II to outflow);
Turbidity (depths of visibility, pond I, II to outflow);
Odour;
Material in suspension, measured in the Imhoff glass after 2 hours;
Measurement of amount of sludge (from pumping time of helical pump);
Checking of starting and finishing water level in pressure boiler gauges (where the water from manure lagoons is used again for flushing purposes).

2.5.2 Special operating instructions

2.5.2.1 Screens and clarification ditches

All obstructions must be removed from screens as required. They should be cleaned periodically with a water jet.

Clarification chambers and ditches, or anaerobic ponds (or preliminary clarification tanks), should be charged alternately where possible in accordance with the special operating requirements.

2.5.2.2 Sewage ponds

In the practical operation of sewage ponds factors which influence the purification process must be borne in mind. Any material, for example, which floats on the surface of the pond has a twofold influence on its operation:

1. it impedes the surface absorption of oxygen from the air, and
2. it reduces the amount of light received by the euphotic zone and affecting the photosynthesis.

Loose straw, oils, emulsified greases and other such substances which may sometimes be added to the pond water in order to reduce evaporation and odour, in every case impair the purification process. Such floating substances, therefore, should be kept away from the surface of the pond.

The following are a few additional main points which should be borne in mind in the application of the sewage pond method[99].

2.5.2.2.1 Overloading

If a sewage pond is heavily overloaded, hygienically dangerous conditions may result. The load per unit volume should therefore be carefully calculated.

In overloaded ponds more bubbles come to the surface (CH_4 and H_2S) and this is associated with the development of odours.

The discontinuous input of water from reservoirs into sewage ponds has an impairing effect on the purification process, since these waters show a comparatively high biochemical oxygen consumption. It is therefore recommended that reservoir waters be conducted separately to a tank, whence they are fed continuously to the sewage pond.

2.5.2.2.2 Variable loading

Variable loading of sewage ponds has an unfavourable effect on the biological decomposition process. Therefore, animal faeces and other substances that impose heavy loads on the sewage pond should be fed in at regular intervals in order to preserve the biological equilibrium of the pond. The aerobic microorganisms cannot live without organic sewage; they adjust to a quite definite organic substance content in the sewage pond. Therefore, when the loads change radically, there are periods in which anaerobic conditions can arise.

2.5.2.2.3 Water weeds

One reason for the recommendation[129] that pond systems be given a depth of 1.00 m is the growth of water plants on the bottom of the ponds. Most of the incident light is absorbed in the upper layers of the water, so that the water weeds in the layers below cannot develop strongly.

In any case the weeds at the edges of the pond down to the bottom of the pond should be kept down. Both mechanical and chemical methods of combatting water weeds are possible. In the case of chemical methods, however, the extent to which the biology of the sewage pond may be influenced, if at all, has yet to be investigated. Suitable herbicides for combatting the water weeds are "Dalapon" (active substance: the sodium salt of α-α-dichlorpropionic acid), and especially aminotriazine derivatives and chlorates.

2.5.2.2.4 Depositing of sludge

With correct loading of the ponds the layers of sludge that collect are very small. In North Dakota[45], for example, it has been calculated that the layer of sludge particles deposited in an oxidation pond cannot become thicker than 2.5 cm in 135 years.

In stabilization ponds and also in the anaerobic cells of manure lagoons, the layers of sludge being deposited can become considerably thicker. Where solid and liquid faecal matter is introduced, desludging of the ponds every 3 to 5 years is necessary, since otherwise the biological effectiveness of the pond systems will be impaired (reduction of volume). Under the conditions prevailing in East Germany, and assuming that mechanical preclarification of the sewage at its introduction into an upstream anaerobic pond is practised, removal of the aerobic cells from the sewage ponds is unecessary.

2.5.2 Maintenance

Desludging of mechanical clarification systems should be carried out as required, an average of once or twice a year, may be suggested. The operation should be conducted so that about 1/6 of the digestor sludge should remain for inoculation of the new sludge enetering the system. After desludging, the clarification ditches should be refilled with fresh water. Input and output channels should be checked as well as intermediate passages in partitions to ensure adequate ventilation and continuous drainage.

The functioning of sewage ponds should be checked by proper inspectors once or twice a week. The pond systems require no special maintenance or servicing, since they operate automatically on biological, biochemical and physical principles.

The community should appoint an officer in charge of maintenance, care and servicing of the sewage drainage systems, who will also observe the operation of the pond systems and will take care of any disturbances that may arise and will make a record of it.

2.6 Economic considerations

For correct appraisal of the cost of the sewage pond process some comparative economic figures on the various sewage purification plants for rural communities in East Germany may be cited. According to investigations of the Hydrological Board Küste-Warnow-Peene, Stralsund, the prime cost in MDN/m^3 sewage per year for amortization, maintenance in continuous operation of the system are shown in Table XI.

It is obvious from Table XI that the prime cost drops with increasing number of subscribers. It is noteworthy that the mechanical clarification systems which in their functioning do not meet hygienic requirements, entail almost equal prime costs to oxidation ditches and intensive activated sludge tanks. The latter type of installation is especially important where smaller numbers of subscribers are involved.

The investigations(125) further show that the prime costs are increased for biological purification of the sewage with subsequent treatment of the soil using the purified sewage. The suggested variants(125), however, are economical , since only with treatment of the soil using the sewage do we get a return of 15 to 22% of the capital investment.

When small clarification plants, which cannot give a satisfactory clarifying effect, are built, investment costs between 200 and 360 MDN/EGW are required(125). According to the author's investigations(99), the investment and prime costs of certain oxidation ponds constructed in East Germany are as indicated in Table XII.

Although the investment costs of construction of sewage pond systems may vary greatly, since they entail not only the sewage treatment plants but also the sewage drain piping, the prime costs for the purification of the sewage are relatively low at 0.25 MDN/m^3. This is linked directly to the functioning of the pond systems, since, as already mentioned, sewage ponds require little maintenance and are very reliable. However, the capital costs can also be reduced by the use of machinery in construction. These come to approximately 10,000 MDN/hectare of pond area to be constructed. By selecting implements and machines recommended by Teipel(106), the earthworks can for the most part be mechanized and the costs can be still further reduced.

Below we present an example of calculation of the operating and annual cost for the oxidation pond system at Kemnitz/Greifswald. The amount of soil water collected from 50 inhabitants at 100 litres/E · d each comes to 5 m^3/d. With the addition of 100% groundwater we get an annual sewage volume of 3650 m^3. The operating and annual costs (prime cost) relative to sewage drain and sewage treatment systems were calculated as follows:

1. Sewage drain system

1 AK, 4 hours/month, 4.00 MDN/hour	= 192.000 MDN
Maintenance cost 0.1% of 2100.00 MDN	= 2.10 MDN
3% amortization of 2100.00 MDN	= 563.00 MDN
	257.10 MDN/a

For every m³ of sewage carried, we get a cost of

$$\frac{257{,}10\ \text{MDN/a}}{3\,650\ \text{m}^3/\text{a}} \mathrel{\widehat{=}} \underline{0{,}07\ \text{MDN/m}^3}$$

2. Sewage treatment plants

1 AK, 16 hours/month, 4.00 MDN/hour	= 768.00 MDN
maintenance cost 0.2% of 3600.00 MDN	= 7.20 MDN
3% amortization of 3600.00 MDN	= 108.00 MDN
	883.20 MDN/a

Cost per m³ purified sewage:

$$\frac{883{,}20\ \text{MDN/a}}{3\,200\ \text{m}^3/\text{a}} \mathrel{\widehat{=}} \underline{0{,}27\ \text{MDN/m}^3}$$

In every case the sewage should be employed for agricultural or fisheries purposes, so that a direct economic return can be obtained.

The possibility recommended by Holler and Newrzella[135] of spraying sewage on agricultural land acquires even greater importance in conjunction with the sewage pond methods (the sewage can be retained in the pond in summer and winter).

The purification and possibilities of utilization of sewage has been reported by various authors, including[3,9,17,23,34,43,44,49,50,51,55,60,68,75,76,78,80,93,96,98,100,101,107,115,120,127]. In doing so hygienic aspects must always be borne in mind, in order to avoid infections and contamination of drinking water[9,17,57,75,119].

The possibility suggested by Professor Janert of utilizing the purified water draining from oxidation ponds for subsurface irrigation, should be considered. This appears all the more important inasmuch as this possibility is receiving international attention since in this way the agricultural utilization of sewage can be best carried out from the hygienic and economic point of view.

It is noteworthy that sewage nutrients are especially well converted by carp into fish proteins and may thereby become productive[23,67,68,94-96].

Sewage fish ponds can give yields per hectare of as much as 450 to 500 kp per annum. Yields per hectare up to even a thousand kp per year may be attained. Table XIII gives a number of carp yield figures as attained in East Germany[99].

Properly conducted sewage fish ponds, therefore, constitute a profitable branch of production. Gross receipt of 1175.00 MDN to 1200.00 MDN[99] per hectare are not infrequent, so that apart from the possibility of carrying out sewage purification and specifically eliminating the nutrients in these ponds, the sewage fish pond method also constitutes an economically logical utilization of organically soiled sewage.

3. Recommendation of the Application of the Sewage Pond Method in East Germany

3.1 General recommendations

For the application of the sewage pond method in East Germany the following points are made and the following recommendations given:

The sewage pond method is a technically simple, hygienically reliable, and relatively cheap method of purification which is characterized by natural biological, biochemical and physical processes. However, these processes are not comparable to a natural biological purification process in a flowing body of water[36,61,72,102,103].

Functioning

With an effective pond area of approximately 1 to 5 m^2 EGW, pig or cattle, the sewage is purified, depending on the biochemical oxygen consumption, in about 30 days. The average pond depth should be Zm = 1.00 m. 2 or 3 ponds should be connected in series or should be operated alternately. The BOD_5 decomposition is more than 90%, and the pathogenic germs are reduced by more than 90%. The contamination of rivers and other bodies of water is largely eliminated by the application of the pond method.

Possible combinations (purification of household sewage)

In East Germany there are hygienically satisfactory and economically favourable combinations for the purification of household sewage by the sewage pond method. These are as follows:

1. Combination of a mechanical clarification of settlement plant with oxidation ponds. The utilization of sewage or its further retention can be as follows:

   Spraying, with the observance of retention times as provided for in TGL 6466, introduction into carp rearing ponds in conjunction with fresh water feed during the summer months;
   underground irrigation in conjunction with Professor Janert's plastic foil drainage, the amounts of water and its distribution being determined in accordance with the "Hoffmann formula";
   introduction into receivers and other bodies of water without danger of overloading (eutrophication, contamination).

2. Combination of overloaded, partially biological purification plants with oxidation ponds, and utilization as above.
3. The introduction of the solid and liquid sewage into sewage ponds for anaerobic and aerobic processing in the stabilization pond.

The combinations described under 1 to 3 should be tested in other experimental systems in East Germany.

Possible combinations (purification of barn sewage)

With the gradual application of industrial production methods in the socialistic agriculture of East Germany the sewage pond method, in the form of manure lagoons, acquires special importance for pig farms that employ water-carrier manure disposal methods, poultry combines and cattle farms. The solid and liquid manure is purified in the so-called "manure lagoon". The following possible combinations result:

1. Initial mechanical treatment in clarification or sedimentation plants and if need be solid retention, in combination with 2 or 3 manure lagoons, and subsequent underground irrigation or sprinkling. Suitable pond surface area figures are 1.25 to 2.50 m^2 per pig and volume figures 2.00 to 3.00 m^3 per pig are recommended. The average depth of pond should be Zm 1.20 m.

   For cattle farms a pond surface area of 0.50 to 1.50 m^2/head and at a depth of approximately 1.50 m are recommended.
2. As under 1, with recirculation of part of the purified sewage from pond II or III and its utilization as flush water in the water-carrier manure removal method (saving of water).
3. Introduction of the solid and liquid manure from piggeries into the manure lagoons for purification without previous mechanical clarification, and agricultural utilization as under 1 (anaerobic and aerobic ponds).

Cost of construction

The construction costs can be kept low. For speed and drainage construction cement, wood and iron are suitable materials. The dam structures are all earthworks all of which can be accomplished in a fully mechanized manner with bulldozers.

Operating costs

The operating costs are very low, since sewage ponds require virtually no maintenance and are nevertheless trouble-free in comparison with other purification plants, since the natural self purification process proceeds in summer and winter in the pond without human intervention.

Since the sewage pond method is a very simple one, it should be applied wherever the required natural conditions are present (gradient ponds or depressions capable of development, twice as exposed to the wind, protection of ground water assured).

In rural communities with up to 2500 inhabitants, and in the purification or processing of animal faeces, especially from piggeries, the sewage pond method should be employed more frequently in future than hitherto, since it can help to close the gap in effective sewage purification systems for rural settlements.

The following guide indices are offered to the planner as hint for the planning of sewage ponds. These guide indices and abbreviations have been assembled from an examination of the literature(7,40,109) and from our own investigations(99)*.

3.2 Guide figures for the planning of sewage ponds

3.2.1 For planning oxidation ponds, quantities of water greater than or equal 500 EGW, 0.1 m^3/EGW

1. Pond area, volume and BOD_5 load (pond type Om, initial mechanical clarification, 35g BOD_5 E · d)

   F_o = 4.00-5.00 m^2/EGW = 8.75-7.00 g BOD_5/m^2

   V_o = 4.00-5.00 m^3/EGW = 8.75-7.00 g BOD_5/m^3

   Z_m = 1.00 m, z_a = 0.20 m, z_{max} = 1.20 m

   $t_o = \frac{4.00}{0.10} = 40$ d, $t_o = \frac{5.00}{0.10} = 50$ d

2. Pond area, volume and BOD_5 load (pond type Ob, initial partial biological cleaning at 35 g BOD_5/E · d)

   $F_{o/b}$ = 2.00-2.50 m^2/EGW = 5.00-3.50 g BOD_5/m^2

   $V_{o/b}$ = 2.00-2.50 m^3/EGW = 5.00-3.50 g BOD_5/m^3

   Z_m = 0.90m, z_a = 0.20 m, z_{max} = 1.10 m

   $t_{o/b} = \frac{2.00}{0.10} = 20$ d, $t_{o/b} = \frac{2.50}{0.30} = 25$ d

3. Pond area, volume and BOD_5 load
   (Pond type OS, initial mechanical purification, oxidation ponds combined with drainage-seepage systems, distance of suction pipes, about 2.00 m, depth of pond bottom, approximately 0.50 to 0.60 m)**

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* I particularly wish to thank Doctor habil. Uhlmann, Liepzig, for sending me the research report on "Oxydationsteiche" (Oxidation ponds) and his kind assistance in the clarification of a number of critical questions in the problem of the sewage pond method.

** The guide figures are not final, since not enough systems are in operation which might have been investigated thoroughly.

$F_{o/8} = 2.00\text{-}3.00\ m^2/EGW = 17.50\text{-}11.66\ g\ BOD_5/m^2$
$V_{o/8} = 2.00\text{-}3.00\ m^3/EGW = 17.50\text{-}11.66\ g\ BOD_5/m^3$
$Z_m = 1.00\ m,\ z_a = 0.20\ m,\ z_{max} = 1.20\ m$
$t_{o/8} = \frac{2.00}{0.10} = 20\ d,\quad t_{o/8} = \frac{3.00}{0.10} = 30\ d$

3.2.2 For the planning of stabilization ponds and manure lagoons, sewage quantities greater than or equal to 500 EGW, 0.1 m^3/EGW · d

1. Pond area, volume and BOD_5 load for manure lagoons (pigs) 1 pig (75 kp weight) = (1.9 EGW) = 102.6 g BOD_5/d. (BOD_5 values of 300 g and more can often be detected.) With initial mechanical clarification: BOD_5 reduced by about 50%, hence 51.3 g BOD_5 per pig · d, pond type Sj)*

$F_j = 1.25\text{-}2.50\ m^2/pig = 41.04\text{-}20.25\ g\ BOD_5/m^2$
$V_j = 2.00\text{-}3.00\ m^3/pig = 25.65\text{-}17.10\ g\ BOD_5/m^3$
$Z_m = 1.20\ m,\ z_a = 0.60\ m,\ z_{max} = 1.80\ m$
$t_j = \frac{2.00}{0.05} = 40\ d,\ t_j = \frac{3.00}{0.05} = 60\ d$

2. Pond area, volume and BOD_5 load for stabilization pond, type Sn

$F_8 = 1.00\text{-}2.00\ m^2/EGW = 54.00\text{-}27.00\ g\ BOD_5/m^2$
$F_8 = 1.00\text{-}2.00\ m^3/EGW = 54.00\text{-}27.00\ g\ BOD_5/m^3$
$Z_m = 1.00\ m,\ z_a = 0.50\ m,\ z_{max} = 1.50\ m$
$t_s = \frac{1.00}{0.10} = 10\ d,\quad t_s = \frac{2.00}{0.10} = 20\ d$

These heavily loaded sewage ponds are of minor importance, because they may produce odours ("industrial ponds").

3. Area, volume and BOD_5 load for anaerobic preliminary clarification tanks, pond type SV

$F_{s/v} = 0.20\text{-}0.30\ m^2/EGW = 270.00\text{-}178.82\ g\ BOD_5/m^2$
$V_{s/v} = 0.10\text{-}0.15\ m^3/EGW = 540.00\text{-}357.64\ g\ BOD_5/m^3$
$Z_m = 0.50\ m,\ z_a = 0.30\ m,\ z_{max} = 0.70\ m$
$t_{s/v} = \frac{0.10}{0.10} = 1\ d,\ t_{o/v} = \frac{0.15}{0.10} = 1.5\ d$

3.2.3 For the planning of sewage fish ponds, sewage quantities greater than or equal to 500 EGW, 0.1 m^3/EGW · d (initial mechanical purification)

1. Pond area, volume and BOD_5 load, pond type Ff, (quantity of fresh water for dilution taken into account in tf)

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* The guide figures are not final, since not enough systems are in operation which might have been investigated thoroughly.

$F_f = 50.00\text{-}60.00\ m^2/EGW = 0.70\text{-}0.58\ g\ BOD_5/m^2$
$V_f = 50.00\text{-}60.00\ m^3/EGW = 0.70\text{-}0.58\ g\ BOD_5/m^3$
$Z_m = 1.00\ m,\ z_a = 0.80\ m,\ z_{max} = 1.20\ m$
$t_f = \frac{50.00}{1.00} = 50\ d,\ t_f = \frac{60.00}{1.00} = 60\ d$

2. Pond area, volume and BOD_5 loads, type Fo and Fb (combined oxidation and sewage fish pond system, oxidation pond to be calculated as under 3.2.1. Quantity of fresh water for dilution taken into account in t_{fo})
$F_{f/o} = 5.00\text{-}10.00\ m^2/EGW = 0.70\text{-}0.35\ g\ BOD_5/m^2$
$V_{f/o} = 5.00\text{-}10.00\ m^3/EGW = 0.70\text{-}0.35\ g\ BOD_5/m^3$
$Z_m = 1.00\ m,\ z_a = 0.80\ m,\ z_{max} = 1.20\ m$
$t_{f/o} = \frac{5.00}{0.5} = 10\ d,\ t_{f/o} = \frac{10.00}{0.5} = 20\ d$

With subscriber values of smaller than or equal 500 EGW an additional 10% should be added to the pond surface. The depth z_m should then be varied between 0.50 m and 1.00 m.

Nomenclature: F_o = pond area for oxidation ponds (m^2), V_o = pond volume for oxidation ponds (m^3), z_m = mean impoundage depth of ponds (m), z_a = admissible minimum impoundage depth of ponds (m), z_{max} = permissible maximum impoundage depth of ponds (m), t_o = theoretical retention time of sewage in the oxidation ponds in days (d), $F_{o/s}$, $V_{o/s}$, $t_{o/s}$ = as before but combined with drainage-seepage system, $F_{s/v}$, $V_{s/v}$, $t_{s/v}$, = as before but for anaerobic preliminary clarification tanks, or ponds, F_s, V_s, t_s = as before, but for stabilization ponds, F_j, V_j, t_j = as before, but for manure lagoons, F_f, V_f, t_f = as before, but for sewage fish ponds, $F_{f/o}$, $V_{f/o}$, $t_{f/o}$, = as before but for combined oxidation and sewage fish ponds, etc.

4. Summary and Prospects

A number of sewage purification systems for rural communities that are under discussion have been described. These involve mechanical and biological systems, which cannot always be operated without hygienic considerations. Even in rural communities preference must be given gradually to the biological methods, and sewage ponds in this case appear particularly suitable. It should be borne in mind, however, that the natural conditions must first be carefully investigated before a given purification method is finally decided upon.

In particular the following systems have been dealt with:

1. The sewage pond method with the principles of applicability and operation that must generally be considered.
   Depending on local conditions, oxidation ponds, stabilization ponds and manure lagoons can be employed.

2. The variants for purification of sewage in rural communities. A number of problems are discussed in connection with the oxidation and sewage fish pond system of the community of Bandelin by Greifswald. The sewage fish ponds are supplied with fresh water. An oxidation pond system is described with reference to the sewage purification plant which was erected for the social and administration building at Kemnitz by Greifswald.
3. The purification of barn sewage and faeces in the manure lagoon. The manure lagoon method is preferred in piggeries using water carrier sewage removal.

The biologically purified sewage in sewage ponds can be used for fisheries or for sprinkling on or irrigation beneath agricultural lands.

If insufficient fresh water is available the flushing out of faecal matter from piggeries may be accomplished by recirculation from oxidation ponds II or III.

Apart from the further planning and construction of sewage ponds in rural settlements, recently the sewage pond method has been partially applied in the City of Greifswald with about 50,000 inhabitants, in the form of a combined oxidation pond and drainage-seepage system for the biological post-purification of the sewage. After purification in oxidation ponds the sewage is to be utilized for spraying on agricultural land, so that the nutrient sewage will no longer flow uselessly into the Greifswald ground.

No such sewage purification with subsequent agricultural utilization of the sewage as contemplated here exists as yet in Central Europe.

By observance of the solutions outlined in the present paper, a contribution can be made to the hygienically satisfactory purification of organically soiled sewage from rural communities and to its economically advantageous utilization. To the well-known statement of Thales von Milet "the best is water" it then remains only to add "the worst is not sewage".

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Table I

Purification effect of various sewage purification methods

Sewage purification method	Susp. Susb. mg/l	BOD_5 consumption mg/l	Coliform germ count per ml
1. Raw sewage, not initially purified	250-350	240-400	250,000-1,000,000
2. Discharge, treated mechanically and in part biologically	80-130	180-260	100,000 - 500,000
3. Oxidation ditches	80-130	50-80	100,000 - 500,000
4. Other biological purification systems	20-60	40-100	50,000 - 250,000
5. Vollk mechanical and biological purification	20-40	10-30	3,000 - 10,000
6. Septic tanks (24 hours retention time)	30-200	50-200	10,000 - 500,000
7. Anaerobic ponds (3 months retention time)	50-200	50-200	5,000 - 250,000
8. Stabilization ponds (Dakota type, 20 days retention time)	50-150	20-200	50 - 5,000
9. Oxidation ponds (Oswald type, 3 to 20 days retention time)	20-150	10-100	0 - 1,000

Table II

Subscriber values per hectare of pond area and characteristic figures for various oxidation pond systems

Place	Load per unit area E/ha	Tot. no. of inhabitants connected to system	No. of ponds An-aero-bic	No. of ponds Aerobic	Total area (ha)	Depth (m)	Retention time (days)	Red. of BOD_5 (total)	Red. of germ and bacterial counts or coil titre %
Gundorf near Leipzig	2500	1500	1	2	0.6	1.2	25	92	96
Melbourne, Australia (87)	1126	1690	2	1	1.5	0.9	21	84	99
Shoemaker, California (10)	1000	40000	0	4	40.0	0.9	25	86	99
Blankenfelde near Berlin	2600	360	0	3	0.14	1.0	28	99	99
Richmond [80], [81]	10000	5000	0	1	0.5	0.7	3/20	99	99

Table III

Effect of oxidation ponds on the BOD_5 and germ count

	BOD_5 in mg/l		Total germ count	Germ counts per ml	
	Raw sewage	Output	Raw sewage	Coliforms Raw Sewage	Outflow Germ count
Shoemaker	143	34	49,000	10,000	1
Fuglebjerg	148	11	83,000	24,000	33
Lund	158	20	3,500,000	100,000	30
Munich *	350	30	840,000	95,000	50
Schönerlinde *	216	35	1,000,000	400,000	10
Blankenfelde	197	9	450,000	90,000	6
Bandelin **	205	4	520,000	53,000	2

* Used as sewage fish ponds. Schönerlinde = sewage filtered through ground

** No oxidation ponds strictly speaking, but now still heavily charged with sewage and high BOD_5 load from leaves falling into it.

Table IV

Pond management indices

Management: Number of ponds and Ø size:

Name of responsible officer: Pond size:

Charge					Fish obtained					
		No. of fish					No. of fish			
Date	Kind of fish	Ind. P	Total kp	Supplier	Date	Kind of fish	Total	Indiv-idual	Buyer	Remarks

Fertilizers Fodders kp/ha	Fodders (natural artificial) kp/ha	Total fish yield kp/ha	Total cost MDN	Net profit		Remarks
				MDN	MDN/ha	

Table V

Population equivalence and pond load values

	Population equivalence	Pond load values*				
1 human	1.00	250.0	375.0	500.0	625.0	750.0
1 horse	11.30	21.7	33.0	44.2	55.2	66.2
1 cow **	16.40	15.2	23.0	30.5	38.0	35.5
1 sheep	2.45	100.2	150.2	200.5	250.0	300.5
1 pig ***	1.90	125.7	177.2	250.2	350.0	377.0
1 fowl	0.014	17,500.0	26,250.0	35,000.00	43,750.00	52,500.0

* Converted to 1 hectare of pond surface.

** With initial mechanical clarification 0.50 m^2 - 1.50 m^2/head (cattle farms).

*** With initial mechanical clarification 1.25 m^2 - 2.50 m^2 per pig.

Table VI

Analysis values and population equivalence

Kind of sewage	pH	N mg/l	Amount l/head·day	BOD_5 mg/l	Population equivalence per head · days
Liquid Manure					
One room open stable	9.0	170	1.5-2.0	3300	0.0575
Feeding stable	8.5	868	1.0-1.5	3658	0.0339
Resting stable	8.5	571	1.5-2.0	2785	0.0258
Drain from floor					
One room open stable	9.0	260	7-23 *	1200	0.293
Sewage					
Initial and final pens cattle exchange	7.5	53	20-30 *	2475	1.063
Barn, run	9.5	500	10-25 *	780	0.346
Milking house sewage					
Fresh accumulation	7.5	130	4.5	990	81.76 **
Last compartment, KLG	7.0	90	0.3-1.8	810	20.69 ***
Liquid manure, cattle barn					
Many rowed barns	8.5	2621	-	16028	12.67
Open court barns	8.0	846	-	4984	4.35
Sewage, pigs					
Run and large sty	8.0	440	20-35	4200	1.39
Water carrier Cleaning	6.0	700	140-300	5000	17.31
Water flush Danish barns	6.0	4800	62-78	9700	38.88

* 40-75 mm precipitation/month

** Milking houses rate of sewage accumulation 4.5 $m^3 \cdot d$

*** Population equivalence refers to daytime accumulation of sewage during month

Table VII

Average physical and chemical results of investigations of sewage from the Andershof/Stralsund piggery

Time of investigation	Water temp. °C	pH value	BOD_5 Mg/l	$KMnO_4$ mg/l	Total N	Total PO_4
Immediately after taking samples	11	7.8	1890	3790	604	101
After 5 hours settlement time (laboratory)	15	7.9	1850	3780	604	100
After 24 hours settlement time (laboratory)	18	7.8	1430	3010	605	87
After 48 hours settlement time (laboratory)	18	7.8	1190	2540	600	91
After 96 hours settlement time (laboratory)	18	7.9	680	2120	601	97

Table VIII

Characteristic designations for oxidation ponds

Pond type Om = Oxidation pond (mechanical pretreatment)	
Load:	70.00 - 87.50 kg BOD_5 per hectare · d with an average sewage retention time of 40 days. The retention time may also be less, if the effectiveness of the artificial ventilation and illumination are intensified.
Number of ponds:	For subscriber values below 500 population equivalence = 1 - 2 ponds, For subscriber values above 500 population equivalence = 2 -3 ponds, which can be connected in parallel or in series
Depth of ponds:	For subscriber values below 500 population equivalence on the average 0.60 - 0.80 m, for values above 500 population equivalence on the average 1.00 m depth. Since the anaerobic activity of the microorganisms is undesired, excessive depths are to be avoided in the installation of ponds.
Input and drainage arrangement:	Input should be to the bottom of the pond. With small subscriber values the inlet structures can be incorporated in the earth bank of pond I (double corrugated tile of wood or cement). With a large number of subscribers and several ponds it should be put in the center of pond I. The drain structure should be a bottom drain.
Slope:	The slope depends on the kind of ground. Sandy soil: inside slope = 1 : 2 to 3, outside slope = 1 : 2. Loamy ground: inside slope = 1:1.5 to 2, outside slope = 1:1 to 1.5. 0.20 m freeboard must be observed when pouring first dams.
Pond type Ob = oxidation ponds (initial partial biological purification)	
Load:	35.00 - 50.00 kg BOD_5/hectare · d with an average sewage retention time of 15 days. Number, depth of ponds, arrangement of input drains and slopes substantially as above.
Pond type Os = oxidation ponds (drainage-seepage system)	
Load:	116.60 - 175.00 kg BOD_5/hectare · d with an average sewage retention time of 25 days. Before final loading of the ponds seepage tests should be carried out so that the retention time may be accurately determined. Number, depth of ponds, arrangement of input drains and slopes substantially as above.

Table IX

Characteristics for stabilization ponds

Pond type Sj = stabilization ponds (manure lagoons)

Load: 205.20 - 410.40 kg BOD_5/ha · d with an average sewage retention time of 50 days. The retention time refers to the entire system, including the anaerobically and aerobically operating ponds.

Number of ponds: At least four ponds in all. Ponds I and II operate anaerobically, ponds III and IV aerobically, owing to decreasing load. Pond I should be subdivided and charged alternately.

Depth of ponds: The mean depth should not substantially exceed 1.20 m. Pond I can be as much as 1.80 m deep, pond II up to 1.50 m.

Input and drainage arrangement: Input to pond I is at the bottom of the pond. Overflows into the next ponds and the final drain should be set up as bottom drains or free falls.

Slope: The slopes depend on the kind of soil.
Sand: inside slope - 1 : 3,
outside slope - 1 : 1.5 to 2.
Loam: inside slope - 1 : 2,
outside slope - 1 : 1 to 1.5.
0.20 m free board to be observed in pouring earth dams.

Pond type Sn = Stabilization ponds (anaerobic ponds)

Load: 270.00 - 540.00 kg BOD_5/ha · d with an average sewage retention time of 15 days ("industrial ponds"). Number, depth of ponds, arrangements of input drains and slopes substantially as above.

Pond type Sv = Stabilization ponds (anaerobic preliminary tanks)

Load: 1788.20 - 2700.00 kg BOD_5/ha · d with an average sewage retention time of 1 day (sewage thus initially purified then goes to oxidation ponds for full biological, aerobic treatment).

Number of ponds: Two ponds which can be operated alternately

Depth of ponds: Average depth is 0.50 m

Arrangement of input and output lines: Simply supported input at the surface of pond.
Output: overflow

Slope: 1:0 (made of cement)

Table X

Characteristics of sewage fish ponds

Pond type Ff = Sewage fish ponds (addition of fresh water)	
Load:	5.80 - 7.00 kg BOD_5/ha · d with an average retention time of 50 days. The retention time depends in the last analysis on the amount of fresh water furnished, which should bear a ratio of 2 to 5 : 1 relative to sewage.
Number of ponds:	The number of ponds depends on local conditions. At least 2 ponds, and preferably more, should be provided.
Depth of ponds:	The mean water depth of the pond should not exceed 1.00 m. In the centre of the ponds (drainage ditches for the purpose of complete emptying) depths up to 1.50 m are permissible.
Arrangement of input and drains:	The mechanically prepurified sewage is introduced into the fresh water pipes where it is mixed before being introduced into the fish pond. It then goes through inlets (0.2 m above the mean water line into the pond. All ponds must be completely drainable by the incorporation of cement or wood tiles.
Slopes:	Slopes depend on the kind of soil, Sandy soil: inside slope = 1 : 2 to 3, outside slope = 1 : 2. Loamy soil: inside slope = 1 : 1.5 to 2, outside slope = 1 : 1 to 1.5. 0.20 m freeboard should be observed in pouring the earth dams.
Pond type Fb = Sewage fish ponds (soil filtered sewage)	
Load:	3.50 - 7.00 kg BOD_5/ha · d with an average sewage retention time of 10 days. The retention time depends on the amount of fresh water supplied. Fresh water supply necessary in summer months. Number, depth of ponds, arrangement of input drains and slopes, substantially as before.
Pond type Fo = Sewage fish ponds (combined with O-type)	
Load:	3.50 - 7.00 kg BOD_5/ha · d with an average sewage retention time of 15 days. Fresh water supply, among other things, necessary. Number, depth of ponds, arrangement of input, drains and slopes substantially as above.

Table XI

Prime costs in MDN/m^3 of mechanical clarification plants, oxidation ditches, and intensive activated sludge tanks

Population equivalence	Mechanical clarification plants MDN/m^3	Oxidation ditches MDN/m^3	Intensive activated sludge tanks MDN/m^3
250	1.10	-	1.19
500	0.55	0.64	0.61
750	0.38	0.43	0.42
1000	0.28	0.33	-

Table XII

Cost of various oxidation ponds

Oxidation ponds	Population equivalence	Investment cost total MDN	Unit investment cost MDN/EGW	Unit prime cost MDN/m^3
Lobejün	650	40,000	61	0.25
Christgrün/Vogtland	475	52,000	109	0.24
Kemnitz/Greifswald	50	5,700	114	0.27
Reuth/Vogtland	655	98,000	150	0.26
Kemnitz/Vogtland	340	47,000	138	0.28

Table XIII

Yield figures from sewage fish ponds

Year	Yield figures Schönerlinde kp/ha	Yield figures Av. for East Germany kp/ha
1960	480.4	434.4
1961	645.1	411.9
1962	478.8	418.6

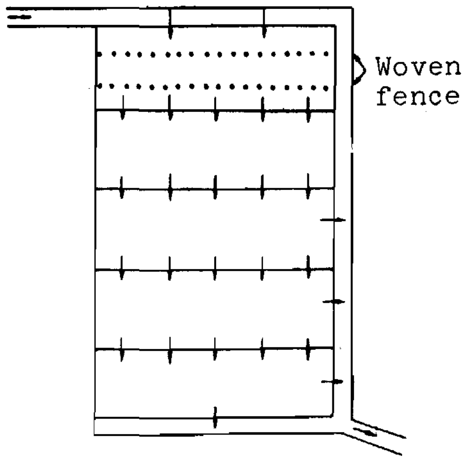

Figure 1

Sketch of the continuously operated sewage pond of Lublino and Luberzi near Moscow

Figure 2

View of the sewage purification plant in Auckland, New Zealand. After initial mechanical purification the sewage is first fed in to anaerobic ponds, then to four aerobic ponds which have a total area of 400 hectares, for full biological post-purification *

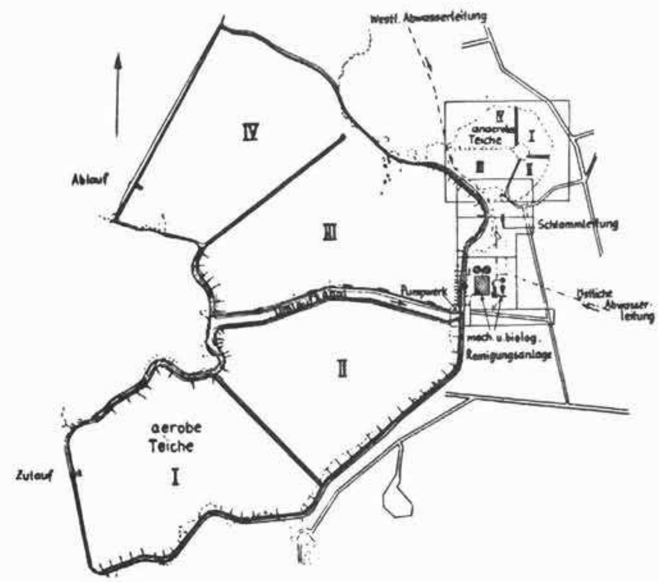

Figure 3

Sketch of the Auckland, New Zealand sewage purification plant

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* For making the original available I am grateful to C.C. Collom, Chief Engineer of the Metropolitan Drainage Board of the City of Auckland, New Zealand.

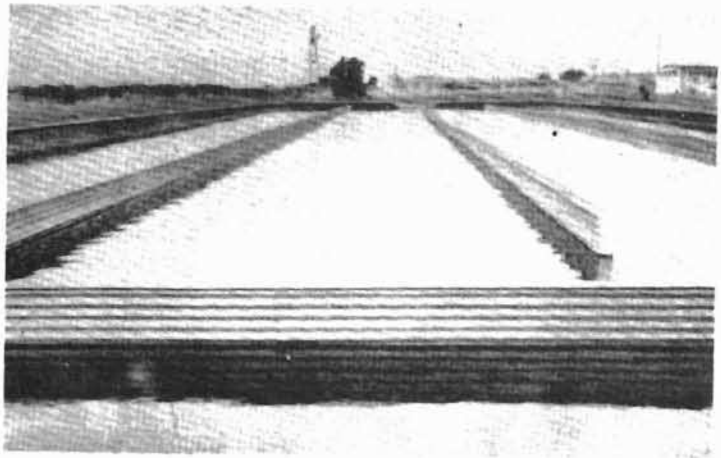
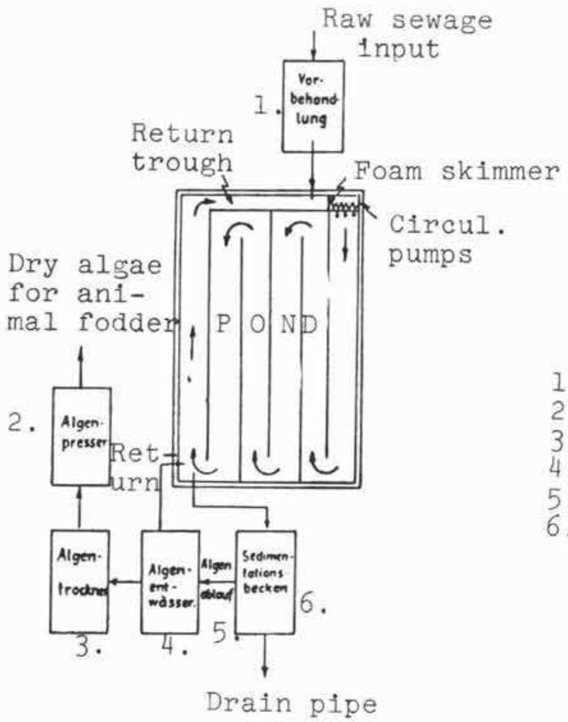


Figure 4

Algal reaction pond according to Professor Oswald, Richmond, California. This pond not only purifies a sewage biologically, but also produces high-protein algae for animal fodder



1. Initial treatment
2. Algae presser
3. Algae drier
4. Algae dehydrator
5. Algae drain line
6. Sedimentation tank

Figure 5

Diagram of Professor Oswald's algal reaction pond

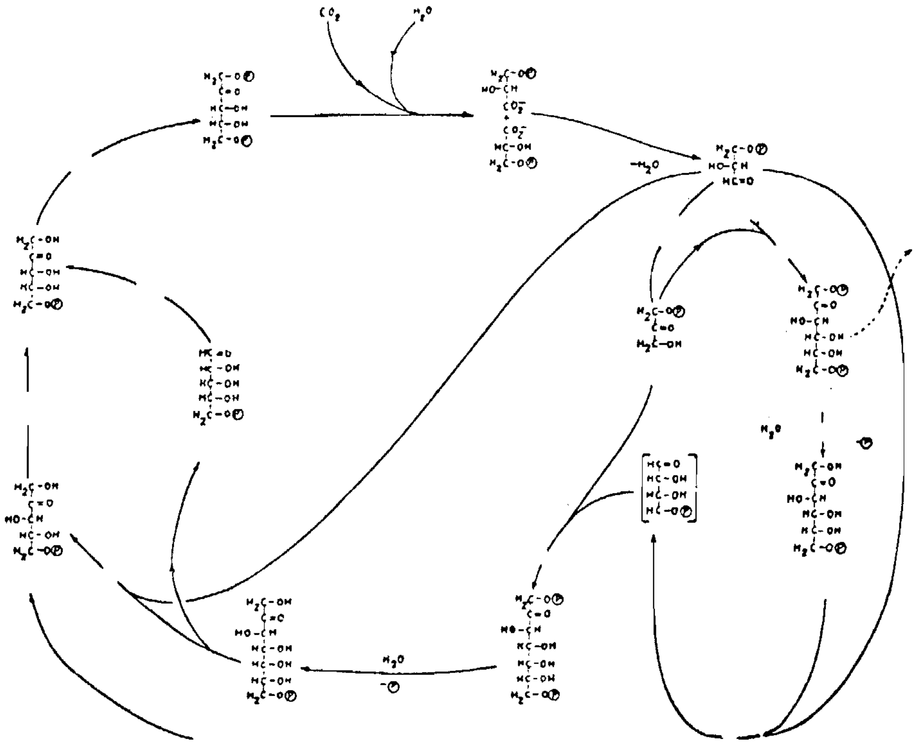


Figure 6

Photosynthesis of sewage systems, examined for chlorella sp./Scenedesmus sp.

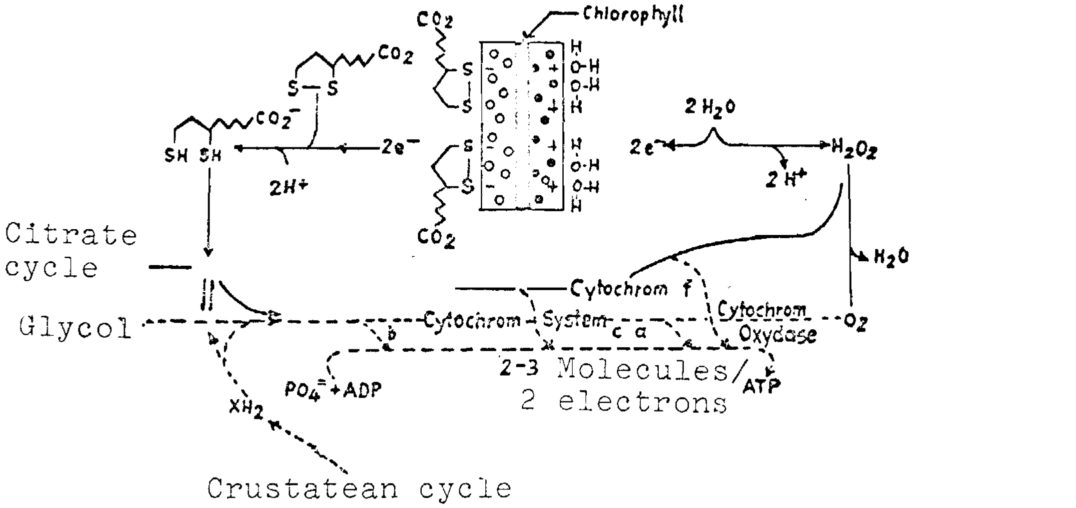


Figure 7

Biochemical processes in the grana of sewage algae, oxidative phase ---, reductive phase ___

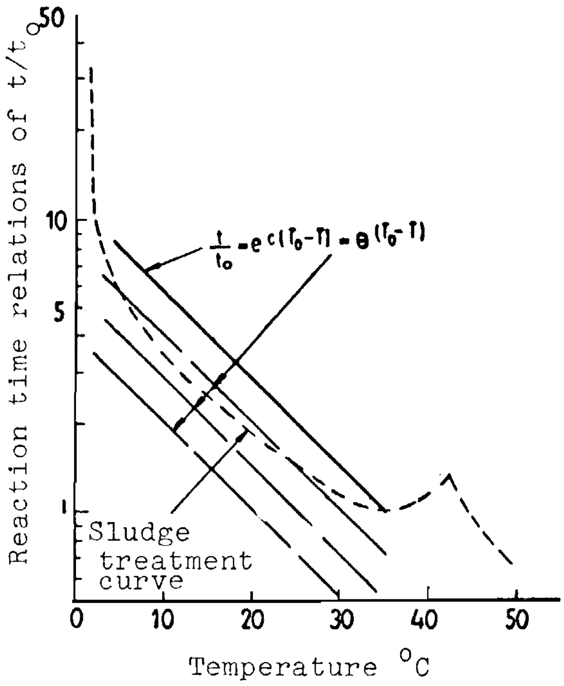


Figure 8

The Van't-Hoff-Arrhenius equation, amended for the reaction time relation in sewage ponds

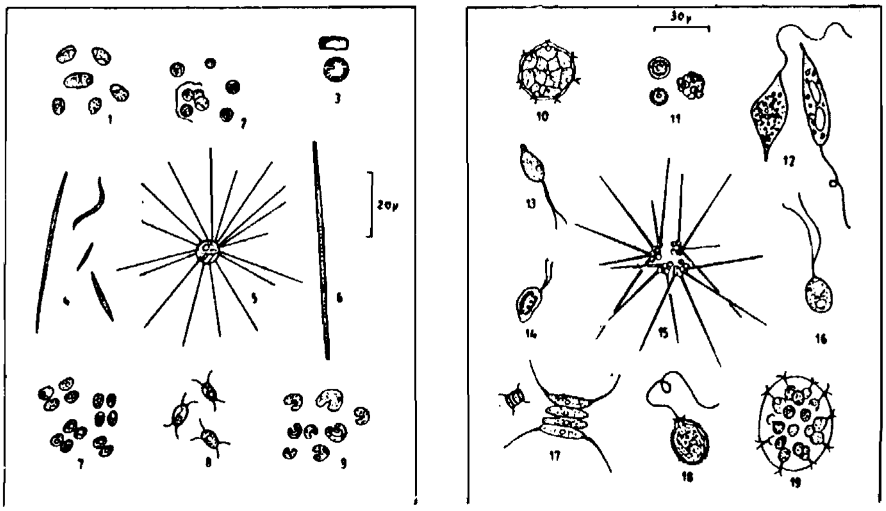


Figure 9

Important algae occurring in the sewage pond

1 Clorella ellipsoidea
2 Chlorella vulgaris
3 Cyclotella operculata
4 Ankistrodesmus sp.
5 Golenkinia radiata
6 Nitzschia palea
7 Crucigenia rectangularis
8 Chodatella quadriseta
9 Selenastrum minutum
12 Pandorina morum
11 Coelastrum microporum
12 Euglena sp.
13 Chlorogonium euchlorum
14 Cryptomonas erosa
15 Micractinium pusillum
16 Chlamydomonas sp.
17 Scenedesmus sp.
18 Trachelomonas sp.
19 Eudorina elegan

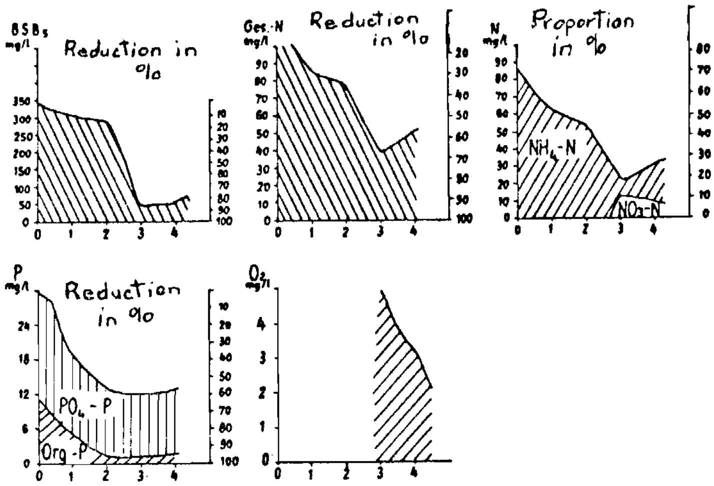


Figure 10

Reduction of BOD_5 and elimination of nutrients, sewage inspection of the purification plant at Greifswald-Ladebow. The results of sewage purification in the oxidation pond were determined in a small pond that was present in nature *

0 Raw sewage.
1 Imhoff tank.
2 Drain ground after 1.
3 Drain ground after 0 - pond (30 d).
4 Drain ground from drainage-seepage system.

* My sincere thanks go to Doctor Schnese and Dr. Schwartz, Greifswald, for their assistance in determining some of the values.

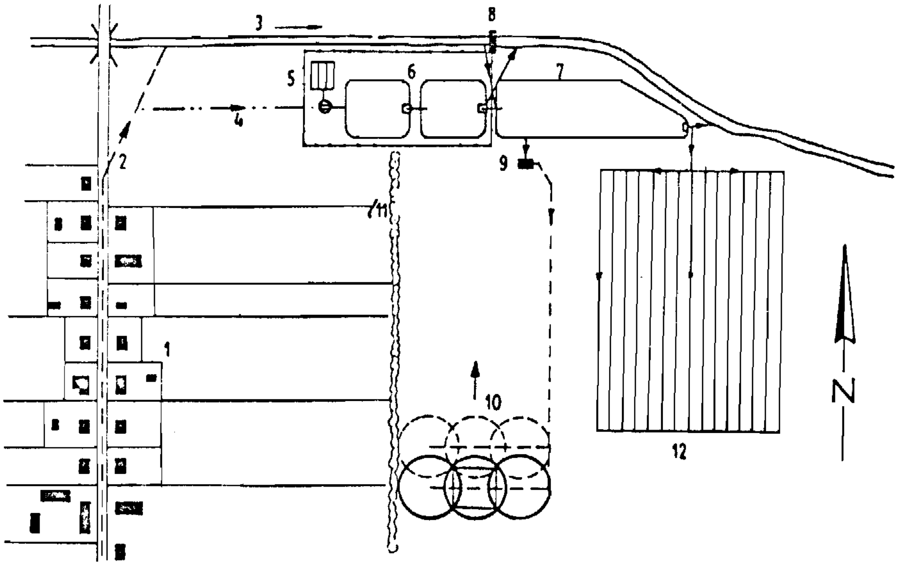


Figure 11

Possibilities of purifying and utilizing organically soiled sewage with the sewage pond method

Legend:

1 Built-up area with hygiene-protection zone on the side of the sewage utilization error (bounded by a wind break hedge).

2 Old sewer, sewage formerly flowed directly into the receivers without being clarified.

3 Receivers insufficiently supplied with water and therefore inadequately purified and overloaded with sewage and contaminated.

4 New sewer leading to the oxidation ponds.

5 Preliminary mechanical clarification of the sewage by Imhoff tank and sludge processing on dry beds, and composting.

6 Oxidation ponds, water depth about 1.00 m, retention time 10 to 30 days, depending on BOD_5 load.

7 Rearing pond for carp, good fattening of fish assured by biologically purified and extremely nutritive sewage.

8 Impounding device for feeding fresh water into the carp pond during the summer months, but required only for emergency.

9 Pumping unit.

10 Spraying area.

12 Underground irrigation system.

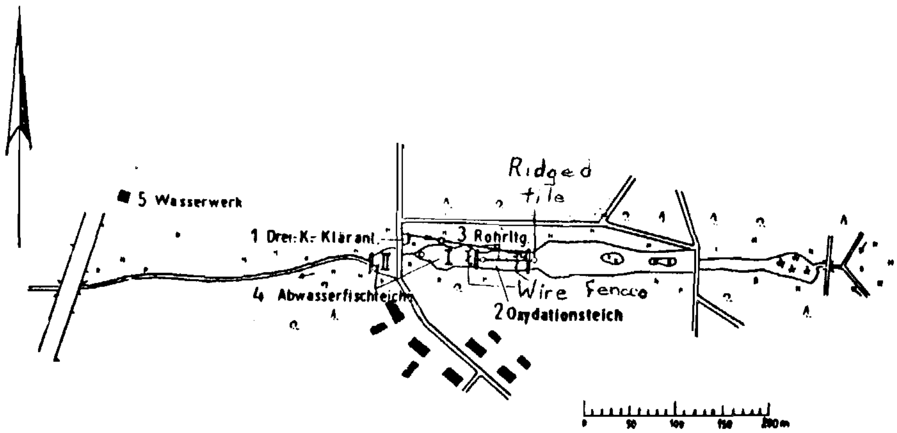


Figure 12

Sewage purification system of the community of Bandelin, Greifswald District (variant 1). This variant is first suggested as an interim solution, after which variant 2 should be built

Legend:

1 Three compartment clarification system (in existence).

2 Oxidation pond (in existence).

3 Pipeline (plan).

4 Sewage fish pond I and II (in existence).

5 Waterworks (in existence). At present, owing to defective purification in the mechanical clarification plant, there is a danger of contamination of drinking water.

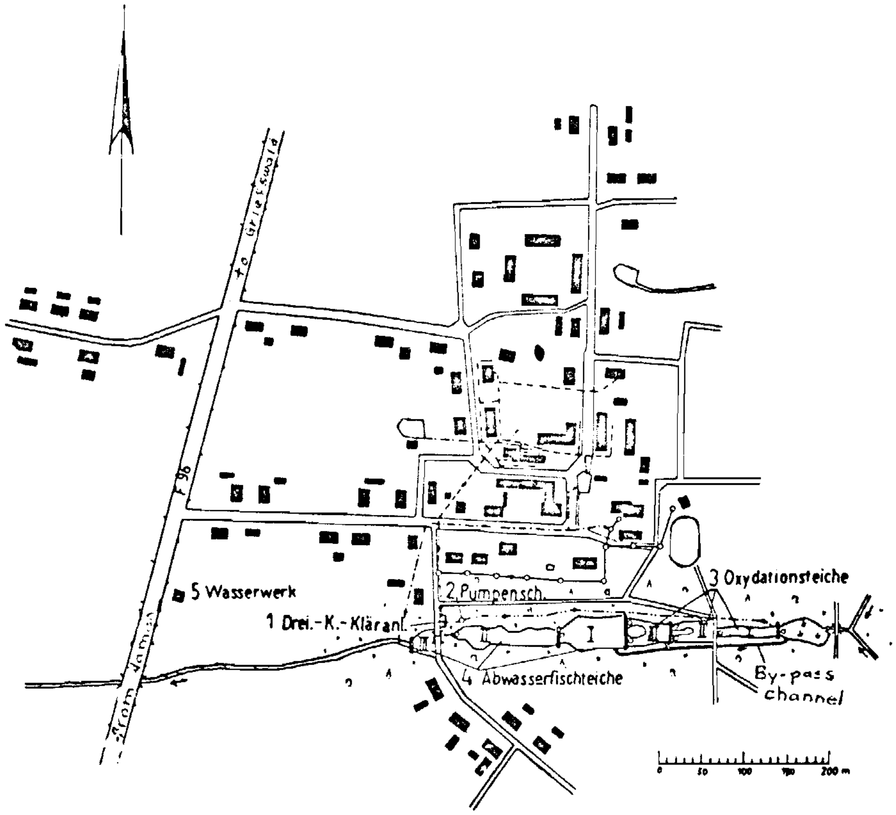


Figure 13

Sewers and sewage purification plant of the community of Bandelin, Greifswald district (variant 2)

Legend:

Existing sewer network,

Existing storm sewer network,

Planned sewer network,

Planned pressure pipeline.

1 Three compartment clarification plant (in existence)

2 Pumping gallery (planned)

3 Oxidation ponds I, II, III (planned)

4 Sewage fish pond I, II, III (planned)

5 Waterworks (in existence). At present there is a danger of contamination of drinking water owing to poor purification effect in the mechanical clarification plant.

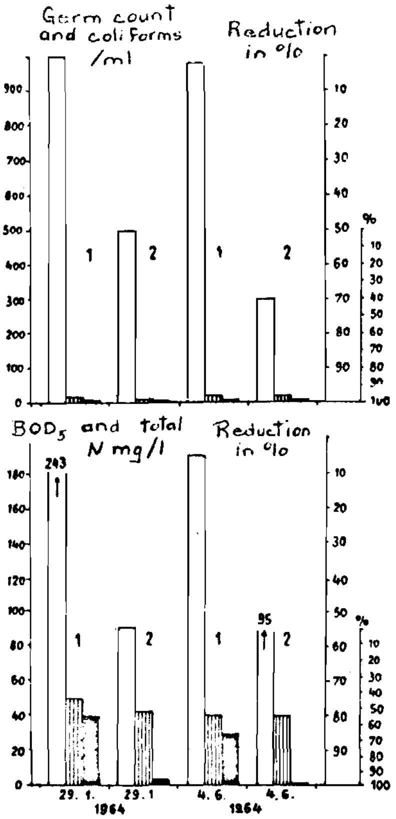


Figure 14

Purification effects by filtration through ground and sewage fish ponds, from the ponds at Schönerlinde near Berlin

☐ Input behind sedimentation tanks

Input into fishponds (ground filter)

Output from fish ponds

1 - germ count or BOD_5, 2 - coliforms or N-values

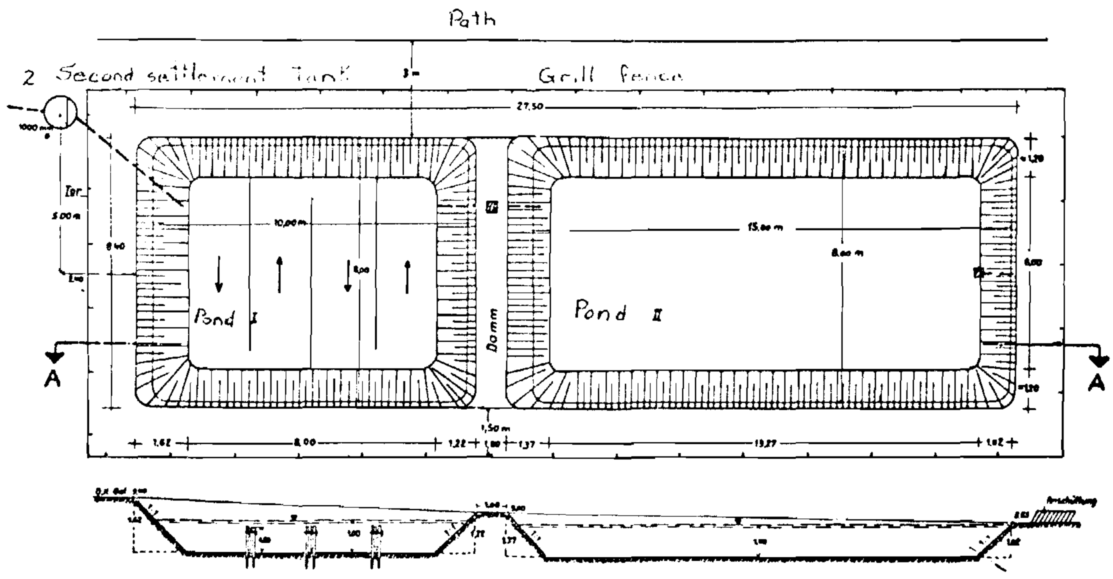


Figure 15

Ground plan and section A-A of oxidation pond system at Kemnitz/Rappenhagen near Greifswald. The sewage is purified in stages and distributed uniformly by plastic foil partitions

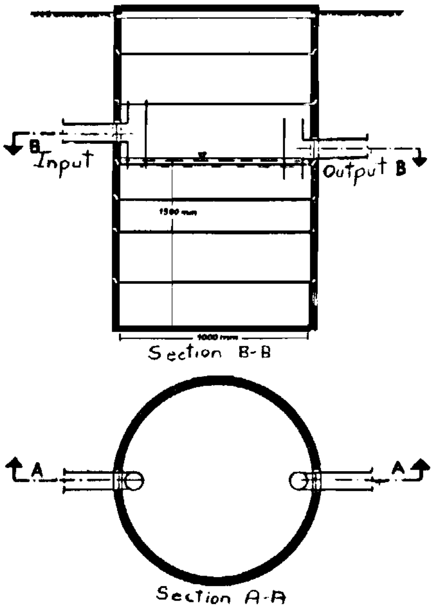


Figure 16

Section of sedimentation plant I for the preliminary purification of the sewage

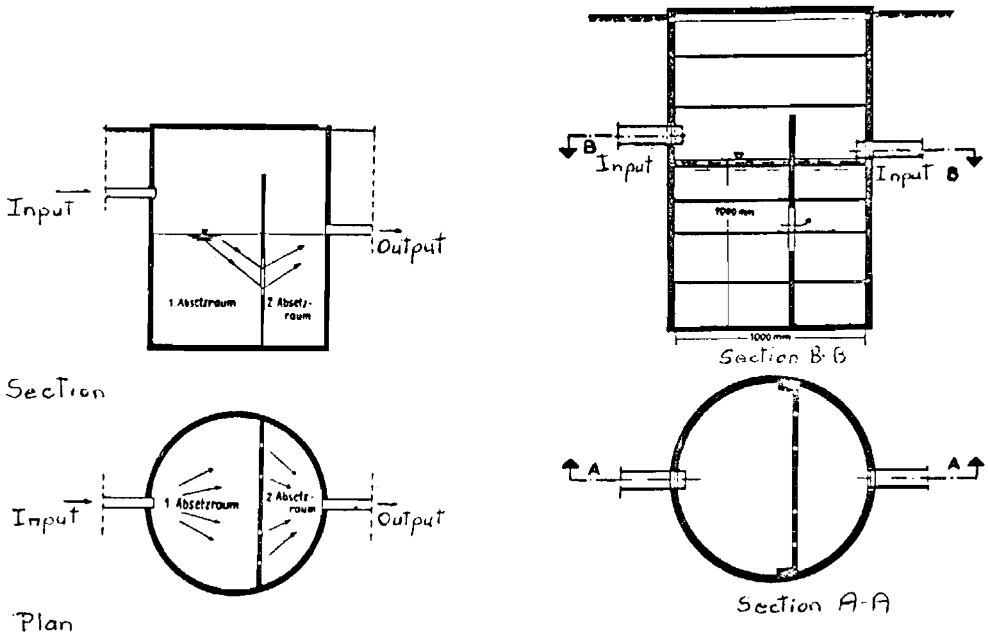


Figure 17

Sedimentation plant 2 for preliminary mechanical purification of sewage

Absetzraum = Sedimentation space

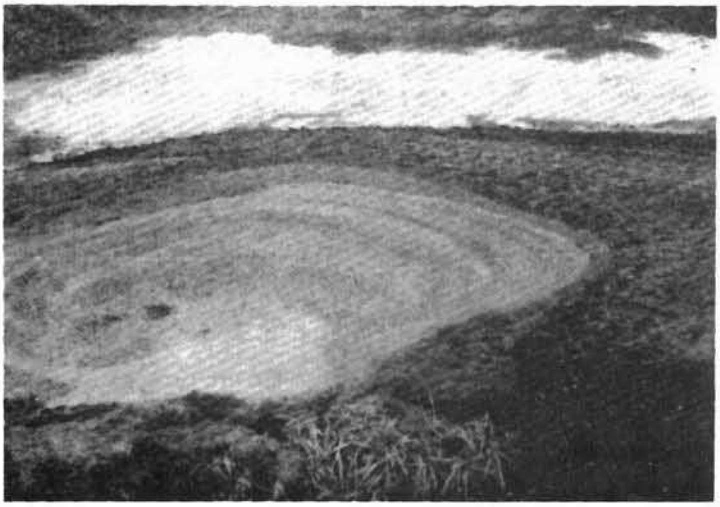


Figure 18

Flies alight on the randomly dropped faeces, so that there is great danger of transmission of pathogenic germs

Figure 19

Conveyance of everything from this pig farm over the terrain not only produces a poor state of affairs, hygienically, but is further questionable in that the water-carried faeces render satisfactory and accident-free operation difficult

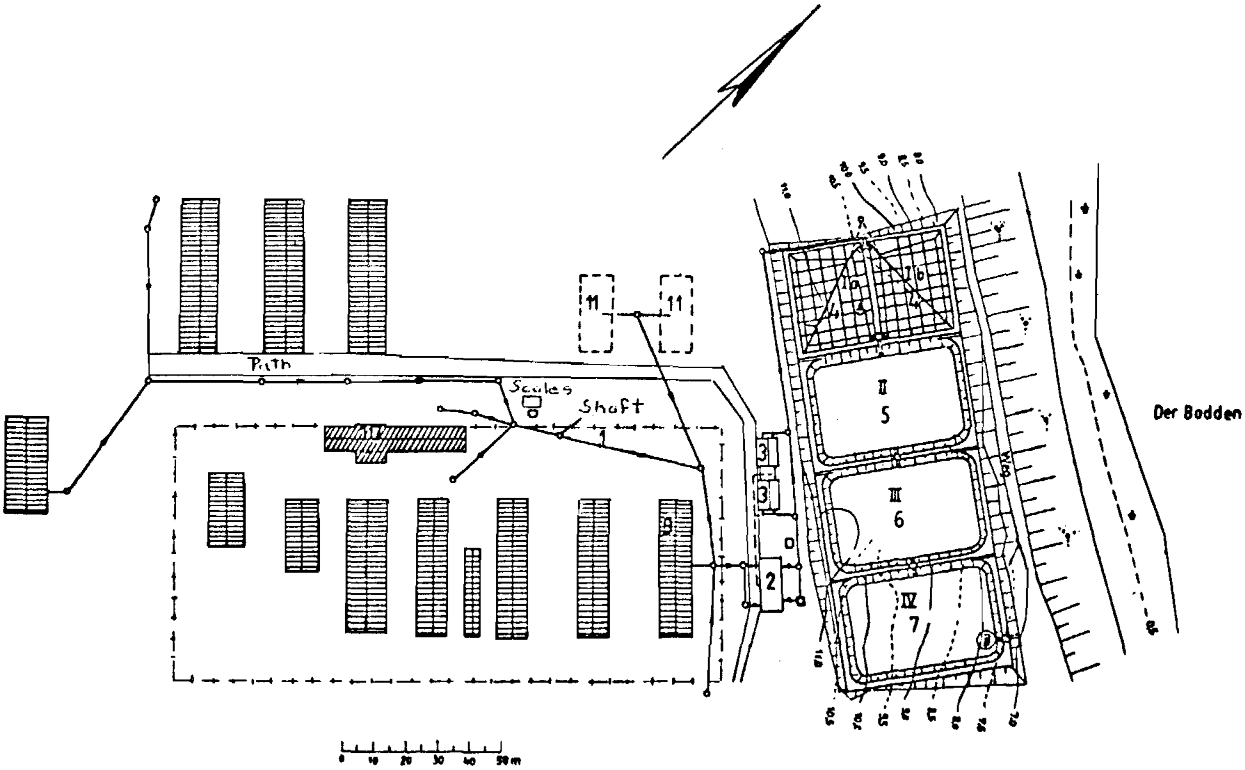


Figure 20

Proposal for hygienically satisfactory treatment of barn sewage in the manure lagoon, example of the plant of the Andershof/Straslund piggery

Legend:

1 Network of sewer.

2 Preliminary clarification tanks.

3 Sludge treatment tanks.

4 Anaerobic ponds Ia and Ib, which should be operated alternately.

5,6 and 7 Manure lagoons.

8 Pumping sump, possibility of removal of purified sewage for agricultural utilization or for reuse as water for flushing

9, 10 Pig barns and buildings.

11 Place for quarantining pigs.

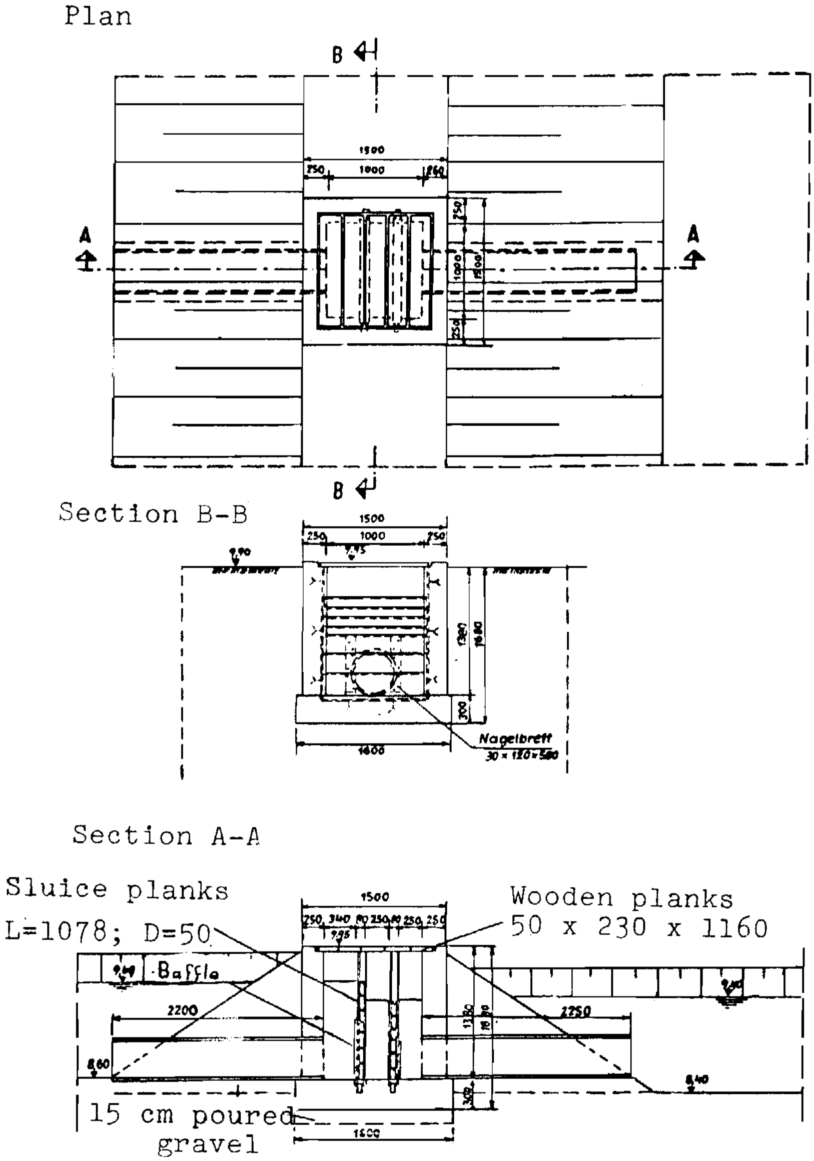


Figure 21

Plan and sections of a sewage pond structure in the Andershof/Stralsund piggery

Figure 22

A pond can be converted to a sewage pond at low costs