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P H O S T R I P
H A N D B O O K

Biological elimination of Phosphorus from domestic sewage by applying the enhanced Phostrip Process

Fourth Edition 1999

Table of Contents

1   INTRODUCTION

An update of the Phostrip Handbook has been necessary for a number of reasons.

Firstly, there has been an enormous amount of research in the field of biological P-elimination which made a revision of the previous edition essential.

Secondly, the Phostrip Process is at last the subject of active scientific evaluation which allows us to back our statements with data based on research and long practical experience in Austria and Germany.

We also have the opportunity to describe the economics of the Phostrip process at several treatment plants according to LAWA guidelines and to present this process
as an alternative to P-elimination, which has lead to its growing acceptance by the authorities.

Whereas with the publication of the previous edition of the Phostrip Handbook, we had to contend with the argument "Not technically feasible", today the Phostrip Process is fully accepted by the ATV as a powerful Bio-P process.

The handbook should not be regarded as an advertising brochure for a process that can cure all problems, but rather an attempt to set out objectively the problem of phosphorus in sewage and suggests a solution that is environmentally sustainable and, from an economic viewpoint, long term and future-oriented, deserving the careful consideration of all interested parties.

The Phostrip Process will not be economically viable if used in treatment plants where the P-limits can be achieved by using the cheapest Fe-salts and the sludge removal and salting of the receiving water costs little or nothing. If a more expensive precipitation agent is required (e.g. to prevent desludging), or when the

sludge removal is a significant cost factor or when the volume of activated sludge should be kept down, then the Phostrip Process is commercially advantageous.

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2   WHY REMOVE PHOSPHORUS?

Phosphorus, in the forms to be found in sewage, is neither poisonous nor a health hazard. On the contrary, phosphorus is a component of many cell structures and the metabolism of animals and plants. Phosphorus occurs in sewage in its most highly oxidised forms and is therefore not an oxygen consuming substance.

Nevertheless, phosphorus is a "problem" because in an aquatic environment, it is generally a limiting factor for the development of organisms. That means that the concentration of phosphates determines the extent to which e.g. algae (Phytoplankton) can develop. The key role of this substance is particularly evident when one realises that 1g of PO_4-P enables the development of 100g Phytoplankton. For the aerobic breakdown of this biomes, a further 150g oxygen is required. In other words, the presence of 1g PO_4-P in waterways induces a secondary overhead of 150g BOD_5 (Uhlmann 1982). Phosphorus is therefore a key factor in the process of eutrophication and for this reason the removal of phosphates a crucial factor in the treatment of sewage.

Forsberg and Ryding (1980) give the trophic status of waterways with respect to the total phosphorus concentrations as

Concentrations < 15µg PO_4-P/l are oligitrophic
Concentrations 15-25µg PO_4-P/l are mesotrophic
Concentrations > 25µg PO_4-P/l are eutrophic

From these concentration figures, the importance of phosphate removal from sewage becomes clear.

3   SOURCES OF PHOSPHORUS IN SURFACE WATERWAYS.

In Austria 1996, the phosphate concentrations were estimated to be 7-8 kt/a (Nikolavcic et al. 1998)

Table 1 shows a breakdown of sources and routes of phosphorus into the sewage system. Agriculture is responsible for almost 50% of the total, which results chiefly from erosion and run-off. Households and industry for 24% and 15% respectively. Treated and untreated sewage accounts for 43%.

Route	Source [%]				
	Agriculture	Household	Industry	Other	Total
Erosion	41	0	0	11	52
Ground water	2	2	0	1	5
Untreated sewage	6	6	0	0	12
Effluent from sewage works	0	16	15	0	31
Total	49	24	15	12	100

Table 1. Sources and routes of phosphorus into surface waterways in % of total (1996)

Fig.1 shows the various routes of phosphorus compounds into surface waterways as % of total (1997)
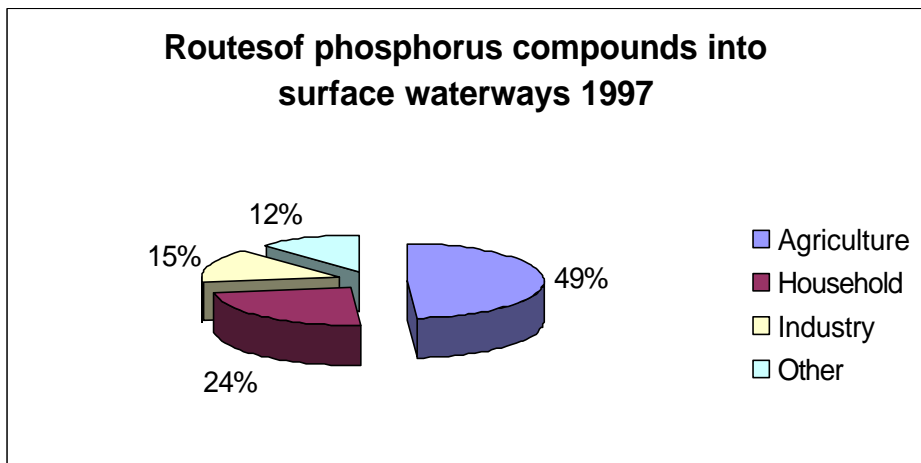
Figure 1. Routes of phosphorus compounds into surface waterways 1997.

4 ORIGINS OF PHOSPHORUS IN WASTE WATER AND THE CONCENTRATION LEVELS.

The major source of phosphorus in domestic sewage is from human waste. The remainder comes from food scraps and washing powders as well as phosphorus compounds from industrial sources.

Through the introduction of phosphates into washing powders the phosphate levels in household sewage 15 years ago was approx. 5g P/E,d. Following the subsequent reduction and replacement of phosphorus in washing materials, the level has been steadily reduced to about 2g P/E,d (ATV M208).

It has been shown that the phosphorus content of sewage in Austria lies between 1.6-2.0g P/E,d (Kroiß et al. 1997; Buchauer,1996).

Approximately 0.2g P/E,d originates from various household chemicals such as washing-up liquids and soap powder. The remaining 1.4-1.8g P/E,d comes from human waste. Commercial or industrial waste currently accounts for approx. 1.5g P/E,d (Novak, 1995).

Smaller sewage treatment plants are therefore predominantly characterised by phosphorus levels of 1.7g P/E,d. (Andreottola et al. 1994)

5 CHEMISTRY OF PHOSPHATE COMPOUNDS FOUND IN SEWAGE.

The overwhelming proportion of phosphorus found in sewage treatment works is in the form of ortho-phosphates (PO_4^{3-}) or various derivatives thereof. Ortho-phosphates normally make up between 50-80% of the total phosphorus content.

Phosphorus is incorporated into the cells of micro-organisms as ortho-phosphate.

Additionally there is a smaller proportion of condensed phosphorus from washing powders and organically combined phosphorus that can be either in solution or particles. While the condensed phosphates (e.g. Pentasodiumtriphosphate) have been
largely eliminated by the use of phosphate-free washing powders, organic phosphates are still present from foodstuffs, metabolic processes and human waste. Because of the quick hydrolysis rate of phosphates, the quantity of organic phosphorus in sewage is very low (Boll 1998).

6   QUANTITY OF PHOSPHORUS ELIMINATED IN SEWAGE TREATMENT WITHOUT ADDITIONAL MEASURES.

The "Normal P-elimination" in a treatment plant is achieved by incorporating the phosphorus through assimilation and by physical-chemical processes.

The **pysical-chemical elimination** of phosphorus is by settlement of the particulate phosphorus compounds and the absorption of phosphorus by sludge flakes. For this type of P-elimination, only P-compounds that have not yet been hydrolised to ortho-phosphates.
Depending on the duration in the primary settling tank and the state of the P-compounds at the intake, the physical-chemical P-elimination can remove from 10%(ATV worksheet A-131) to a maximum of 30%(Scheer 1994, Buchauer 1996).

The **normal accumulation in the surplus sludge through assimilation** is governed by a minimum ratio of $BOD_5:N_{tot}:P_{tot}$ of 100:5:1 for the aerobic breakdown. Thus, the elimination rate is determined by the ratio of BOD_5 quantity to the P-quantity in the intake to the biological treatment.

In a typical Austrian treatment plant with 60g BOD5/E,d, 11g N/E,d (according to ATV) and 1.8g P/p.e., the actual ratio BOD_5:N_{tot}:P_{tot} is 33:6:1. In other words, the nutrients can never be assimilated in sufficient quantities.

Thus single-stage treatment plants, depending on the size of the primary treatment and the particulate P-concentration in the, can be expected to eliminate a maximum of 35-40% of the phosphates.

The authorities however require a minimum elimination rate of 80%. It is therefore necessary to take additional measures for P-elimination.

Since the limit is defined as a concentration, the amount of remaining phosphorus to be eliminated depends above all on the concentration at the <u>intake</u>.

That means that at treatment plants with a relatively large quantity of extraneous waste water, the amount of phosphorus to be removed (usually linked to the amount of precipitating agent required) can rise significantly after a renovation of the sewer system.
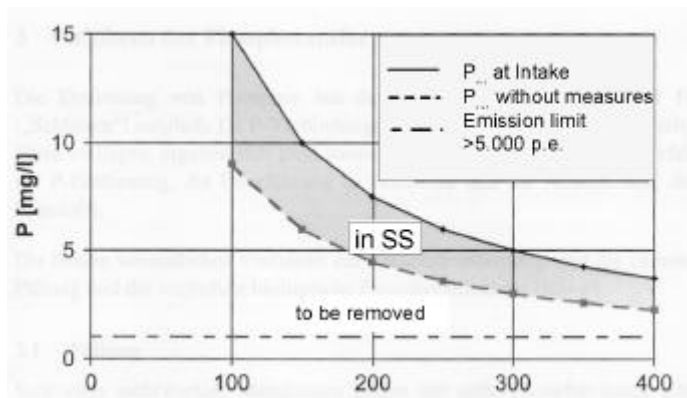
Figure 2. Correlation between intake concentration and the additional phosphorus quantity to be removed (SS = surplus sludge).

7   LEGAL REQUIREMENTS FOR THE REMOVAL OF PHOSPHORUS.

The following is a brief comparison of the legal requirements in Austria, Germany and the EU.

AUSTRIA

Requirements of the 1st Abwasseremissionsverordnung for urban wastewater(19991, 1996).

Treatment plants > 50-500 p.e.	No limits set
Treatment plants > 500-5000 p.e.	
agglomeration < 1000 p.e.	No limits set
agglomeration > 1000 p.e.	Total-P $\leq$ 2.0 mg/l
Treatment plants > 5000 p.e.	Total-P $\leq$ 1.0 mg/l
Treatment plants > 10,000 p.e.	Total-P $\leq$ 1.0 mg/l
	Within the catchment area of a national or international lake, Total-P $\leq$ 0.5 mg/l

Measuring the discharge level.
- In a treatment plants of Class II (> 1000 p.e.), Class III or Class IV the total-P is to be measured from a representative, non-settled, homogenised sample.
- The discharge level for the effluent concentration of total-P is considered to have been met if the arithmetic mean of all measurements in a test year is less than the allowed maximum and no individual measurement exceeds the limit by more than 100%. The minimum number of measurements to be made in a test year is defined according to the size of the treatment plant.

Compliance deadlines for existing treatment plants:

Treatment plants > 15,000- 50,000 p.e   by 01.01.1999
Treatment plants > 2,000- 15,000 p.e.   by 01.01.2001
Treatment plants > 50-   2,000 p.e.   by 01.01.2003

GERMANY

Requirements according to the 'Algemeiner Rahmen-verwaltungsvorschrift über Mindest-anforderungen an das Einleiten von Abwasser in Gewässer (Rahmen AbwasserVwV)' (1996)

Treatment plants > 20,000 p.e.   Total-P $\leq$ 2.0 mg/l

Treatment plants > 100,000 p.e.   Total-P $\leq$ 1.0 mg/l

In some German States, such as Schleßwig-Holstein stricter limits on total-P concentrations in effluent have been imposed.

Measuring the discharge level.

- To determine the discharge level a series of at least 5 measurements are made within a period of two hours, each consisting of random samples taken at intervals of not more than 2 minutes and mixed together.

- The limits are considered to have been met when 4 out of the last 5 tests carried out by the State Water Authority meet the legal requirements and none of the tests exceeds this value by more than 100%.

EU - DIRECTIVES
Directives of the council of 21.5.1991 on the treatment of communal sewage (91/271/EGW).

- In general, similar requirements to those applying in Germany, with the difference that also plants having

an agglomeration with a population equivalent greater than 10.000 must meet discharge limits of $P_{tot} \equiv 2.0mg/l$ to fulfil the formal and technical obligations.

- The compliance deadline for collection and treatment requirements was the end of December 1998, but few countries could actually meet this

8   OPTIONS FOR THE REMOVAL OF PHOSPHORUS FROM SEWAGE.

8.1   "NORMAL P-ELIMINATION" IN THE TREATMENT PLANT.

As described in section 6, up to 40% of the P-load can be eliminated through assimilation and physical-chemical methods, although this is insufficient to meet the legal requirements.

8.2   PHOSPHATE PRECIPITATION.

There are basically three types of chemical suitable for phosphorus precipitation:

a) Iron or Aluminium based acids.
b) Aluminium based alkalis.
c) Slaked Lime.

8.2.1   Precipitation with iron or aluminium based acids.

The most commonly used because they are the most economical, are the iron salts, usually ferric chloride or sulphate. In the main reaction, the iron combines with the phosphates dissolved in the sewage to form insoluble iron phosphate.

$$Fe^{3+} + 3Cl^- + HPO_4^{2-} + 2H^+ \Rightarrow FePO_4 + 3HCl$$
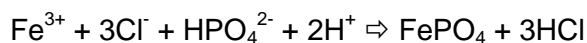
Unfortunately, simultaneous secondary reactions occur, requiring additional quantities of precipitating agent. These competing reactions are:

1. Creation of hydroxides (responsible for low sludge index)
   $$Fe^{3+} + 3Cl^- + 3OH^- + 3H^+ \Rightarrow Fe(OH)_3 + 3HCl$$
2. Complex reactions with organic substances.
3. Absorption reactions.

The overdosing (expressed as ß-value) should, according to ATV, be around 50% (ß-value = 1.5), but in practice usually much higher (ß-value = 2-3).

As can be seen from the reaction equations, in both cases acid salts are created which reduce the acid capacity of the sewage. In sewage with a low acid capacity (low buffer capacity of water), this leads to inhibition of the denitrification.

The efficiency of these types of precipitation agent is very low, as the following calculation will demonstrate:

It is required to calculate the amount of precipitating agent needed for a 25,000 p.e. "ATV standard treatment plant" to give the ATV 131 defined discharge levels. A realistic figure of 1,9g/p.e.,d is taken for the specific P-load. A precipitating agent of ferric chloride is to be used with an effective iron content of 150g per kilo of agent.

From these assumptions we calculate a P_{tot} intake load of 47.5 kg/d of which 12.1 kg is absorbed by assimilation and is sluiced out with the surplus sludge. Additionally, 4.75 kg settled and absorbed particulate phosphorus is to be expected. That leaves 30.6 kg/d remains to be precipitated.

At a ß-value of 1.5, 82.7 kg Fe or 551 kg precipitating agent will be required per day. ***Therefore a half ton of ferric chloride must be tipped into the treatment***

plant per day in order to deposit 30.6 kg Phosphorus.

Purely stochiometrically, this quantity of precipitating agent will lead to up to 100kg acid salts being created per day which will end up in the receiving water.

207 kg of precipitating agent will be removed from the sewage with the surplus sludge.

This additional anorganic sludge quantity leads to a lowering of the allowable volume in the activated sludge tank, which must be compensated for by an additional activated volume in the design stage.

For our "25,000 p.e. Standard treatment plant" with precipitation by iron salts, the size of the activated sludge tank activated sludge must be increased by $770m^3$ (at a MLSS of 4g/l in the activated sludge with 70% N-elimination at 10°C).

It is often argued that this additional volume is unnecessary because the MLSS is raised by the improvement in the sludge index (through the formation of hydroxides in the precipitation), compensating for the additional activated sludge volume.

The sludge index obtained by precipitation can also be achieved in the Phostrip Process but without having to consider additional precipitation sludge!

The metal salts used for precipitation are usually waste products from the treatment of metals with acids. For this reason, they are usually very cheap but are often contaminated by significant concentrations of heavy metals.
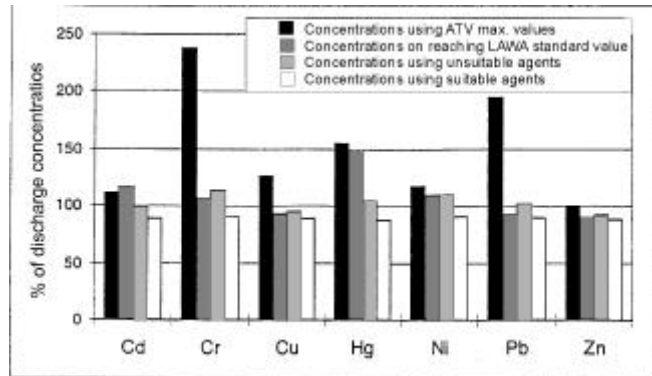
Figure 3. The influence of precipitation agents on the heavy metal concentrations in sludge.(Nowak 1998)

Despite these serious side effects, the acid precipitating agents are the most commonly used.

8.2.2 Precipitation with aluminium based alkalis.

The precipitation of phosphates using sodium aluminate ($Na_2Al_4O_2$) is relatively new. In this alkaline precipitation the aluminium reacts with the phosphate to form aluminium phosphate:

$$Na_2Al_2O_4 + 2PO_4 + H^+ \Rightarrow 2AlPO_4 + 2NaOH + 2H_2O$$
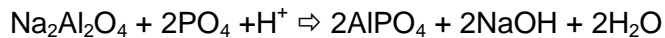
The advantage of this process is that, through the release of alkali, the acid capacity of the sewage is raised rather than lowered. Here too, hydroxide is produced as a side effect which improves the sludge index. Aluminates are relatively pure and, in contrast to the acid metal salts, contain hardly any heavy metals. They are mostly extracted from bauxite by treating it with soda lye. The aluminium content of this agent is very low, generally 7%.

8.2.3 Precipitation with slaked lime.

Here, the presence of Ca^{2+} in the water (responsible for the hardness of the water) is utilised to combine with the phosphate by means of an unstable intermediate phase to produce the thermodynamically stable and insoluble calciumhydroxylapatite, This reaction is only possible at high pH values, when the calcium is released into the water from the hydrogen carbonate.

The purpose of the slaked lime is to raise the pH value, not to provide the Ca^{2+} and any other alkali could equally well be used. The required quantity of lime is independent of the P-concentration and is a function of only the hydraulic load and the acidic capacity of the sewage, making this process especially suitable for high concentrations of phosphates.

The enhanced biological phosphorus elimination process (Bio-P) offers distinct advantages in several aspects over the previously described chemical processes.

8.3 THE ENHANCED BIOLOGICAL PHOSPHORUS ELIMINATION PROCESS.

In many ways better than the chemical processes, but is not yet accepted as a real alternative.

The main reason is undoubtedly the inability to predict the elimination rate in the so-called Mainstream Process. Generally the Bio-P is equated with mainstream processes, although the Phostrip Process, as a Side-stream process, differs in several aspects from the mainstream process.

The main arguments pro and contra biological phosphorus elimination are set out below (after Buchauer 1996)

General advantages of Bio-P	Disadvantages of Mainstream Process
• Significantly lower sludge build-up	• Discharge limits not maintainable
• Higher calorific value of sludge	• Difficult to regulate
• No heavy metals in sludge	
• Lower operating costs	• Floating sludge problem?
• Investment costs overall similar to precipitation	
• No negative effect on the acid	
• capacity	
• No salting of receiving water	
• In combination with precipitation,	
• minimum chemical usage	

In more detail:

Sludge formation:
This is restricted to the polyphosphates contained in cellular matter and the quantities of Mg^{2+} and Ca^{2+} ions to be used for the precipitation reaction. According to literature on the subject, a value of 3.15g MLSS per g polyphosphate is given, representing an increase of 5%. According to the ATV, the sludge increase can be ignored.

Calorific value of the sludge:
Since the bulk of the sludge accumulation during precipitation with metal salts is of inert material, no gas build-up occurs.
Control and regulation of Bio-P:
An effective control of the efficiency of biological mainstream processes is very difficult and usually

discharge levels can only be guaranteed by a final precipitation stage.

Problem of floating sludge:
This is caused by hydrophobic micro-organisms, several species of which have been shown to thrive in Mainstream Processes. *Microthrix* has been shown to be one of the main Bio-P bacteria.

All of these recognised problems of the Bio-P process are confined to the Mainstream Processes and do not affect the Phostrip Process, but since the Mainstream Process is the more widely used, it is also better scientifically documented.

This will also be clear if one bears in mind the working principles and necessary criteria of Bio-P and compares its transfer into the Mainstream and Phostrip processes.

9 MECHANISM AND CONDITIONS FOR BIOLOGICAL P-ELIMINATION.

9.1 BACTERIA STRAINS RESPONSIBLE FOR BIO-P.

Despite the fact that biological sewage treatment is one of the largest applications of biotechnology, there is a considerable imbalance in the understanding of the technical and micro-biological processes concerned. Still very little is known about the changes occurring in communities of organisms within the activated sludge. For a functional sewage treatment process, it is essential to have, for each important conversion phase, the appropriate micro-organisms present in sufficient quantities and state of activity.

In the first micro-biological studies, bacteria of the genus *Acinetobacter* were found to be mainly responsible for increased phosphate accumulation in activated sludge (Boll 1988).

Species of *Acinetobacter* are widespread, gram-negative bacteria and generally considered to be an indispensible aerobic type, although some studies have established their ability to metabolise nitrogen. Short-chain organic acids are among their preferred substrates. Also important is their ability to store polyphosphate and carbon compounds in the form of poly-ß-hydroxy-butyric acid as "storage granula".

Wentzel et al. (1985) developed the basis, still valid today, for the calculation of Bio-P, based on studies of natural and enriched cultures of *Acinetobacter*.

Through the use of new techniques for identifying micro-organisms, it has been shown that *Acinetobacter* must not always be the predominant phosphate incorporating species of bacteria (Röske et al. 1993; Scheer 1995; Helmer 1995).

Streichan et al. (1991) identified around 150 different polyphosphate-storing microbes with sometimes very different metabolisms. It is not surprising therefore, that in treatment works with very different sources of sewage and treatment methods with Bio-P, the spectrum of the polyphosphate absorbing bacteria can vary widely.

In this context Helmer (1995) investigated, based on species identification, the incorporation properties of isolated bacteria strains.. He discovered that under stable process conditions at temperatures of 15-20°C and readily degradable substances, the necessary microbes such as *Acinetobacter, Flavobacterium, Pseudomonadaceae, Moraxella* and *Alcaligenes* make up a large proportion (70%) of the polyphosphate-storing organisms. That means that the current model of Wenzel, which simplifies the phosphate absorption in the aerobic phase and its release in the anaerobic phase, is valid under the stated conditions.

However, Helmer (1995) was also able to show that at low temperatures (5°C) and difficult to break-down substances in the sewage, the optional anaerobic

microbes, such as *Aeromonas, Enterobacteriaceae* and *Staphylococcus*, take over the function of polyphosphate absorption, which means that a release of phosphates in the anaerobic phase to gain energy is no longer necessary. Since, for the previous conditions, the P-elimination is equally efficient, the original model cannot be used in its entirety.

It seems necessary therefore, from the current state of knowledge, to assume some form of symbiotic co-operation between different groups of organisms, whereby the special optional anaerobic micro-organisms become capable of incorporating polyphosphates as well as the hydrolysis of substrates.

9.2   SIMPLIFIED MODEL OF BIO-P

The principal of biological phosphorus removal is based on providing the treatment plant with a supply of micro-organisms (or rather groups of micro-organisms) that are capable of enhanced phosphorus incorporation into their cells as a   polyphosphate. These must therefore be given a selection advantage over the other groups of micro-organisms. This can be done by setting the biocoenosis of the treatment plant, at least for a short period, under strong anaerobic conditions by connecting an anaerobic tank into the sludge cycle.

Polyphosphate-absorbing bacteria are capable of incorporating small pieces of matter, broken down by extra-cellular enzymes in the anaerobic phase whereas other species are not. These organic substances, short-chain organic acids (acetic acid, proprion acid) are stored in the form of poly-ß-butyric acid (PHB) and are immediately available in the anaerobic zone to be metabolised for cell growth, whereas other organisms at this phase have yet to begin with the absorption and breakdown of carbon.
Thus the polyphosphate absorbing organisms have a selection advantage over other organisms, enabling them to multiply and predominate this "niche".

The beneficial side-effect is that the phosphate is used to change places with the carbon. In other words, in order to absorb carbon in the anaerobic phase, and convert it into a PHB, micro-organisms incorporate polyphosphates during the aerobic phase, which are then broken down and exchanged with the carbon in the anaerobic phase .

In this way, phosphates are given off in the anaerobic phase and absorbed in the aerobic. Since the cells in the aerobic phase also proliferate and grow, which outweighs the quantity of phosphate absorbed, the total balance is positive.
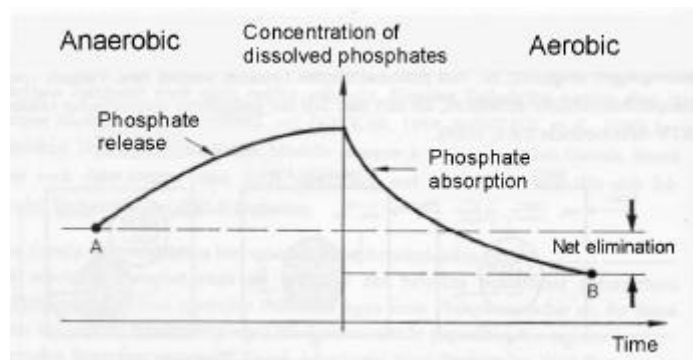
Figure 4 Concentration changes

This P-absorption in the cells is also measurable. In contrast to activated sludge from conventional treatment plants with a phosphate content of 1-2% of the sludge dry-weight, activated sludge with phosphate storage has a much higher content of 7-10% of dry-weight.

A close linear relationship exists between the P-release and the P-absorption (Schönberger 1990, Scheer 1995). Within certain limits, it can be shown that an enhanced P-absorption is possible without a preliminary P_release (Helmer, 1995).

Whereas, according to all theories to date, the P-release in the anaerobic phase was the condition for the P-absorption, the model suggests that it is rather the

absorption of carbon that is essential for the P-absorption in activated sludge.

From the importance of the lower fatty acids to the Bio-P process, it can be deduced that the required elimination rate must always be dependent on the anaerobic phase, but not upon the maximising of the P-release (as earlier thought), rather the maximising of the carbon storage in the Bio-P bacteria (Comeau et al. 1986).

This biological model for Bio-P is today the basis for almost all measurements and calculations although it cannot, in a purely scientific sense, be regarded as proven.
For the sake of completeness, it should be mentioned that, in scientic literature, the hypothesis has been forwarded that the basic mechanism of Bio-P is, at least partly, of a physical-chemical nature (Schönborn et al. 1995; Witt et al. 1995).

From this model we also obtain the necessary criteria for biological P-elimination.

9.3   THE NECESSARY TECHNICAL AND PROCESSING CRITERIA FOR BIOLOGICAL P-ELIMINATION.

From the model used above to explain biological P-elimination, the following criteria have been identified which must be met for a practical application of the model.

- **A maximum of easily degradable organic compounds** in the anaerobic zone, especially short-chain organic acids. At least 50 mg/l organic acids (Buchauer 1996) is required for Bio-P.

- **Long anaerobic contact period**. Since the concentrations, especially of the short-chain organic acids are normally very low (from influent measurements at treatment plants in Tyrol, an

average 30 mg/l (Jarosch 1995)), it is a function of the anaerobic zone to produce acetic acid from the readily degradable compounds (fermentation). According to Buchauer 1996, the extent of the acetic acid production is a function of the total MLSS and the retention time in the anaerobic tank.

- **Strict anaerobic conditions in the anaerobic tank.**
  If oxygen or nitrates find their way into the aerobic tank, the bacteria first absorb the oxygen and then the nitrates. Consequently, the readily degradable substrate is consumed, leaving little over for the bacteria with the greater phosphate capacity, removing their growth advantage and the resultant enrichment of the activated sludge. Purely stoichiometrically, 70 mg/l acetic acid are required for the reduction of 10 mg/l NO_3-N which will be no longer available for the Bio-P process. Since at least 50 mg/l is required for P-release, the problem of nitrates in the anaerobic tank can be clearly seen.

Additionally, the following criteria will give optimum Bio-P process performance:

- **A TKN:BOD$_5$ ratio of 1:<5**
- **A P:BOD$_5$ ratio of 1:<25 in the influent**
- **3 days < sludge age < 20 days**

These ratios are determined by the local influent and the treatment plant characteristics and cannot be regulated.

10 POSSIBILITIES OF ADAPTING THE PRINCIPLES OF BIO-P.

Generally one distinguishes between two methods of Bio-P processing. One, the *Mainstream Process*, is where all the sewage is passed through the anaerobic tank and the other, the *Sidestream Process*, where

only a part of the recirculated sludge is passed through the anaerobic tank. The most common example of a Sidestream Process is the **PHOSTRIP PROCESS**.

10.1 A DESCRIPTION OF THE MAINSTREAM PROCESS.

Here the Bio-P model is realized by passing the entire sludge/sewage mixture through an anaerobic tank. Depending on the location of this tank in the processing cycle, various forms of the Mainstream Process have emerged, some of which have been patented. Figure 5 shows the most important Mainstream Processes.

They all, however, have one thing in common:

The entire sewage stream with all its fluctuations in liquid and solid content passes through the anaerobic tank.

Consequently, neither a constant concentration of short-chain organic acids nor a constant anaerobic contact period is achieved.

The anaerobic contact period is equal to the hydraulic retension time in the tank, which is determined by the rate of flow of the mainstream plus that of the recirculated sludge. The nitrates can only be removed by first passing through a Denitrification stage connected to the anaerobic tank. This configuration, however, means that the valuable short-chain organic acids will be largely used up in the anoxic stage, leaving little over for the Bio-P.
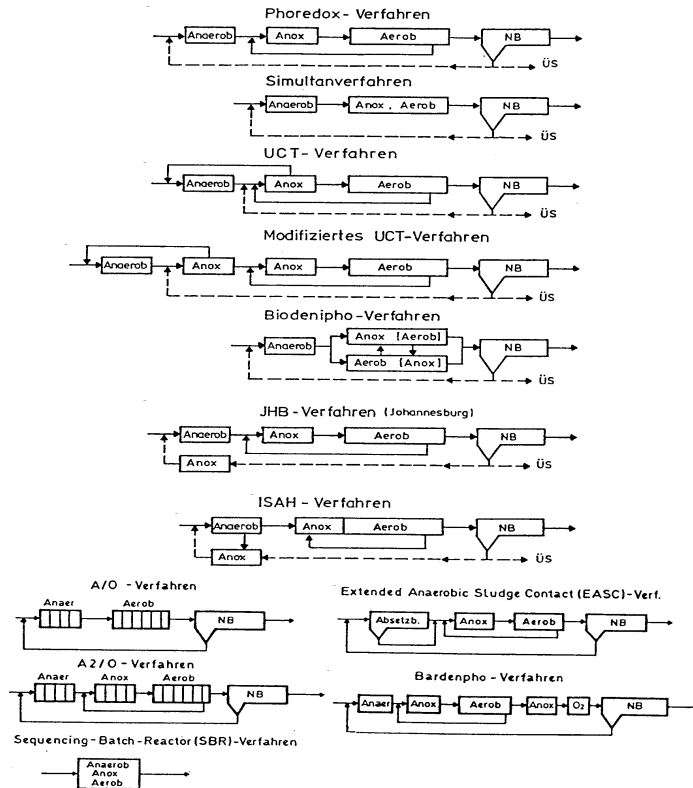
Fig.5. The most important Mainstream processes.

According to ATV report M208, biological elimination only becomes effective after 0.75hr of anaerobic contact period for the incoming and recirculated sludge. From technical papers, anaerobic contact periods of between 0.75-1.0hr under optimal criteria and 1.0-2.0hr under non-optimal criteria are recommended.

These criteria include the concentrations of short-chain organic acids, the ratios $BOD_5:P_{tot}$ and $BOD_5:N$ in the influent. (See also section 9). In an evaluation of tested treatment plants in Germany (Scheer 1995), only 8% were found to have anaerobic contact periods of less than 1.0hr, 66% had between 1.0-2.0hr and the remainder over 2.0hr.

When it comes to the elimination efficiency of these plants, however, there are wide variations in their effectiveness. Although there are models for predicting the values of concentrations in discharge effluents, the differences between the calculated and measured values lie in the region of 1mg/l P_{tot}, i.e. the discharge limit. A statistical study (Scheer 1995), showed that, on average, a P_{tot} elimination rate of 75-80% can be expected, although the higher rate is only achieved at sewage plants using targeted acidification for producing short-chain organic acids. The remainder must, in any case, be precipitated.

Disadvantages of Mainstream Processes.

- *The relatively large volumes required, the anaerobic contact period being dependent on the rate of flow of the mainstream plus that of the recirculated sludge.*
- *The large variations in the process parameters have a negative effect on the already unpredictable rate of elimination.*
- *The poor controllability of the process.*

The following section will show the Phostrip Process to be a practically advantageous and viable economic alternative to currently used precipitation and Bio-P processes.

11 A TECHNICAL DESCRIPTION OF THE PHOSTRIP PROCESS

The Phostrip Process is a method of utilising the advantages of the Bio-P process without having the disadvantages, such as low unstable elimination rate, difficult to control process conditions, a high sludge index, etc.

Central to the improvements over the Mainstream process is that the treatment occurs in a sidestream, i.e. the sludge recirculating stream.

Consequently:

- *The process is independent of fluctuations in influent concentrations.*
- *More biomass can be handled and more micro-organisms given selection advantages (since the MLSS content in the recirculation stream is twice as large as in the main stream of a treatment plant).*
- *More short-chain organic acids can be fermented since the quantity of short-chain organic acids generated is also a function of the total MLSS in the anaerobic zone.*
- *A further improvement is that the contact period of the micro-organisms is separated from the true hydraulic contact period. Consequently a considerably smaller volume can provide up to 10 times the anaerobic contact period of that of the mainstream process.*

The heart of the process is the **Stripper tank [1]**, which in form and function is a standard sludge enricher, normally used for the pre-thickening of the surplus sludge. (Fig. 6)

In this stripper tank:

- A separation of sludge and wastewater takes place through sedimentation and hence an increase in the micro-organism contact period over that of the actual hydraulic contact period.
- A thickening of the sludge by up to 4% (Treatment plant Hofkirchen) is achieved.
- The effective anaerobic storage of sludge is up to 20hr.
- The hydrolysis of particulate COD or activated sludge to an readily degradable, short-chain organic substrate which is essential for the enhanced Bio-P can take place.
- The P-release in the anaerobic phase takes place.

Through the thickening of the sludge, such a large amount of micro-organisms can be given a selection advantage that it is unnecessary to pass the entire sludge recirculating stream through the stripper. In practice, depending on conditions, only 20-45% of the recirculating stream is passed via the **Side-Stream [2]** into the stripper. This significantly reduces the tank volume required for the anaerobic phase.

By moving the process into the sludge recirculating stream, the treatment is completely independent of:

- Influent temperature.
- Fluctuations in the hydraulic volume of the influent.
- COD:PO_4-P ratio in the influent.
- COD:NH_4-N ratio in the influent.

These advantages were confirmed by the results of a study carried out in 1996 by the Frauenhofer Institute, Karlsruhe, the Gesamthochschule, Kassel and the University of Stuttgart at the Phostrip Treatment Plant at Darmstadt Eberstadt.

In the stripper tank, the anaerobically stored micro-organisms, absorbing short-chain organic acids, release phosphate before being returned into the aeration tank via the **Stripper Bed Discharge [3]**.

As a precaution against high nitrate levels in the sludge recirculating stream, a denitrifaction reactor, the **Pre-Stripper [4]**, is recommended. With a relatively short throughflow time, nitrate concentrations can be reduced to about 1-2mg/l NO_3-N which is acceptable for the stripper. Since there is no more useable carbon in the sludge recirculating stream available for denitrification, short-chain organic acids produced in the stripper are diverted into the Pre-Stripper via the **Internal BOD Feed [5]**.

Phosphate concentrations of up to 50mg/l accumulate in the sludge/water mixture on the bed of the stripper

tank and concentrations of short-chain organic acids of up to 80mg/l. These concentrations diminish with decreasing depth towards the surface. In order to distribute the short-chain organic acids throughout the entire volume and to direct a portion of the redissolved phosphates into the stripper overflow, the sludge from the stripper bed is recirculated and the phosphorus and short-chain organic acids thereby washed out. This is referred to as **Internal Recirculation [6]** and in certain circumstances can be connected, together with the Internal BOD Feed, into the pre-stripper.

That the necessary short-chain organic acids are hydrolysed in the stripper in sufficient quantities has been confirmed by the results of a study by Annegg (1996) at the treatment plant Schalchen and also the work of the Frauenhofer Institute, Karlsruhe together with the University of Stuttgart at the Phostrip treatment plant at Darmstadt Eberstadt. ***The addition of an external substrate in all studies produced no further improvement in the P-elimination.***

To make the process more controlable and in order to guarantee that the discharge limits are met, the effluent from the **Stripper Overflow [7]** is subjected to a precipitation stage. Because the overflow contains a very low proportion of the total incoming hydraulic load (about $\frac{1}{10}$ of the total influent volume) but the majority of the redissolved phosphates, this results in a very high P-concentration (in targeted operations, up to 50mg/l PO_4-P).

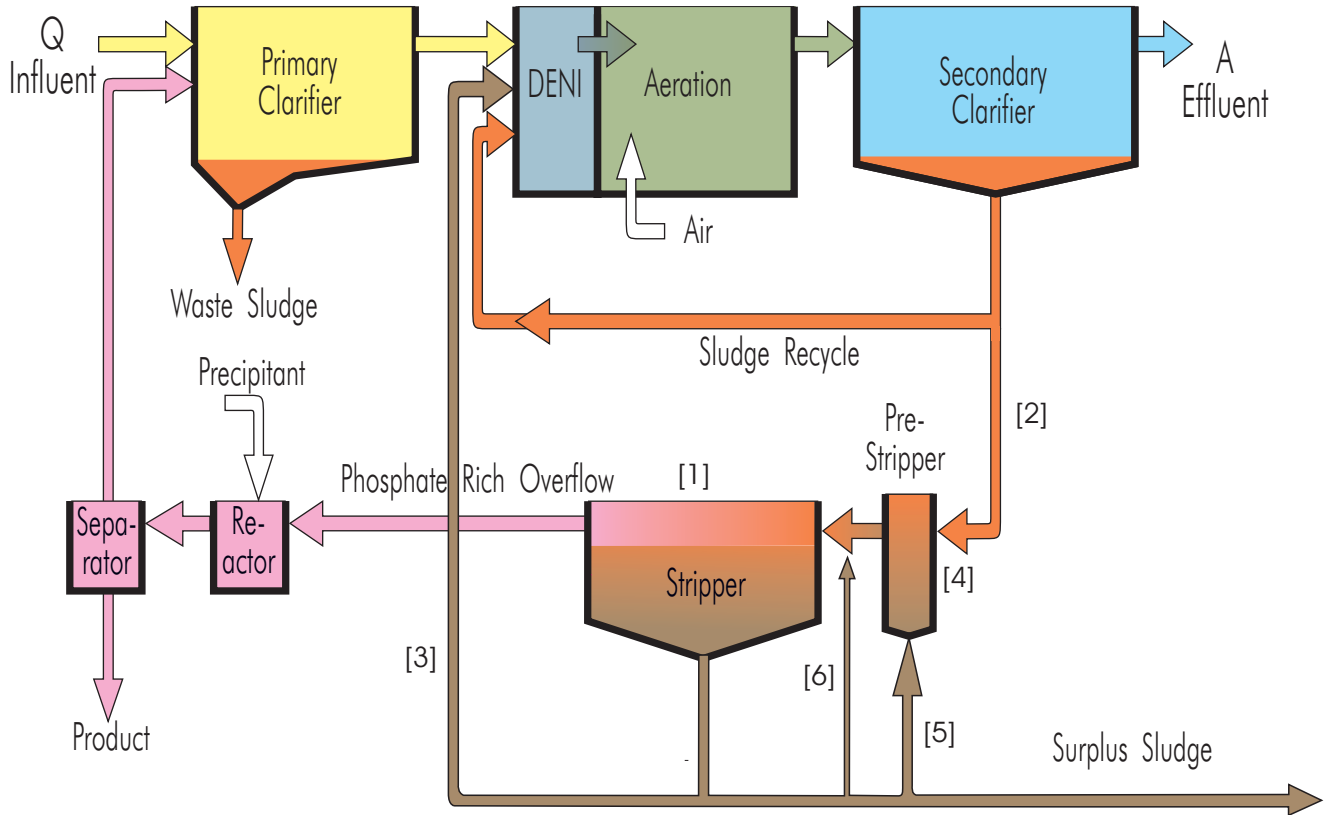# THE EXTENDED PHOSTRIP PROCESS

Figure 6

12 TREATMENT OF THE STRIPPER OVERFLOW IN THE PHOSTRIP PROCESS.

12.1 METHODS OF P-REMOVAL FROM SEWAGE.

The Phostrip process is generally a biological process in which the phosphorus is accumulated in the sludge and removed from the system together with the surplus sludge.

In comparison tests of various Bio-P processes in Germany, by the Gesamthochschule Kassel (Bendzuck 1994), it was clearly shown that the Phostrip Process was the one with the greatest proportion of biological elimination.

The ratio of biologically bound phosphorus in sludge to the amount sluiced out with the stripper overflow is generally dependent on the prevailing conditions, but can be influenced by the process control and the dimensions of the plant itself.

As a rule, it is attempted to remove as much of the phosphates as possible within the surplus sludge.

From an intensive analysis and optimisation of the Phostrip pilot plant at Schalchen, in the course of a masters thesis (Annegg 1996), it was shown that the plant was able to meet the discharge limits without having to precipitate the stripper overflow.

The Phostrip Process of the ARA Hofkirchen was so optimised that 88% of the total extracted phosphorus was removed with the surplus sludge.

12.2 TREATMENT OF THE STRIPPER OVERFLOW.

In most cases, a partial precipitation of PO_4-P in the stripper overflow is necessary but because the P-load is concentrated in a very small volume ($^1/_{10}$ of the average dry weather influent volume), very economic precipitation is possible using slaked lime or sodium hydroxide.

In principle, any precipitation agents can be used. Since only a small volume has to be treated, it is also possible to optimise the pH level for the selected precipitation agent without having to neutralise it afterwards.

For every Phostrip plant, it is guaranteed that the amount of precipitating agent needed to achieve discharge concentrations of less than 1mg/l P_{tot} will not exceed 30% of that required by a Mainstream precipitation process.

In practice, these values have been bettered as the following figures show.

Phostrip plant	Precipitation agent as % Mainstream requirement
Darmstadt Eberstadt (GER)	25 %
Darmstadt Zentral[2] (GER)	30 %
Hofkirchen (AUT)	12 %
Schalchen Pilot plant (AUT)	0 %

The percentage figures are calculated from manufacturers data for the quantities theoretically necessary for simultaneous precipitation of P_{tot}.

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[2] It should be noted that at Darmstadt Central treatment works, it is attempted to extract the phosphorus with the stripper overflow and then to precipitate it with an aluminate agent in order to create a reusable product

A very economical alternative, although only suitable for high phosphorus concentrations in the stripper overflow, is precipitation with slaked lime or sodium hydroxide.

Precipitation takes place in a separate tank, in which slaked lime is added to a pH-regulated section, where a constant pH=9 is maintained, and the phosphate is converted to hydroxylapatite. The precipitate can either be returned to the primary clarifying tank where it is removed with the surplus sludge, or it is processed in an extra separating tank. The separated phosphates are interesting for two reasons:

- The precipitated material contains approximately 40% P_2O_5 in the dried mass. In other words, the best available phosphate fertiliser, the so-called triple-phosphate. In sufficient quantities and in a suitable form, its recovery can be commercially viable.

- The separation ensures that the biological treatment tank is not overloaded with inorganic MLSS, resulting in a larger required tank volume. *So separation of the precipitated material leads to up to 35% smaller aeration tank volumes compared to the simultaneous precipitation process.*

12.3 PHOSPHATE RECOVERY IN THE PHOSTRIP PROCESS.

The extraction of phosphates from sewage has aroused serious interest from all sides of the phosphate industry. At a conference held in Warwick 1999 by CEEP(Centre Europeen d'Etudes des Polyphosphates) on this theme, it was made clear by the industry representatives that the world's phosphate reserves are running out and that the currently extracted phosphates are increasingly contaminated with radio-active elements and cadmium. The phosphate industry (washing powders, fertilisers etc.) has conceded that the use of phosphates

extracted from sewage is becoming increasingly more economically viable.

A study by the IEEP (Institute for European Environmental Policy) showed that theoretically, if the EU Sewage Directive were to be fully implemented in Europe, 211,000-232,000 tons of phosphate could be recovered from urban treatment plants per annum.

Essential for the recovery is that the phosphate can be sluiced out in a concentrated, dissolved form (at least 50-100mg/l) in order to be crystallised and separated out. The first requirement is satisfied by the Phostrip Process in the stripper overflow.

The Phostrip Abwasser Technik GmbH is a member of a Europe-wide research programme for the recovery of phosphates from sewage. The programme is funded by the EU (5th Framework programme for the environment and sustainable development) and by the phosphate and sewage industries.

The aim is to develop a method of sluicing out the phosphates in crystalline form from the concentrated sewage in the stripper overflow or from the P-rich liquors obtained from the fermentation of the surplus sludge.

Currently, two promising methods have emerged:

- Precipitation and crystallisation with calcium (as now done by adding lime to the stripper overflow)
- Precipitation in the form of Struvit (ammonium-calcium-phosphate compound).

13 THE EFFECT OF THE PHOSTRIP PROCESS ON THE OVERALL OPERATION OF A TREATMENT PLANT.

13.1 PHOSTRIP AND THE ACTIVATED SLUDGE SEDIMENTATION PROPERTIES.

In all Austrian treatment plants using the Phostrip Process, a marked improvement in the sludge index was obtained on its introduction.

The sludge index in all treatment plants lay significantly under 100ml/l all year round with minimum values of 60-65ml/l (Hofkirchen treatment plant).

This result was relatively surprising, since according to all previous studies, Bio-P plants tend to favour the formation of species of bacteria which are responsible for a high sludge index.

The excellent activated sludge-sedimentation properties observed in Austrian treatment plants were also confirmed by Barbe (1999). In a Europe-wide comparison of Bio-P treatment plants by the Office International de L'eau, it was found that an optimally operated Bio-P process significantly improved the sludge separation qualities. According to Barbe 1999:
"An anaerobic zone as a contact zone improves the stability of the sludge index under 100ml/l"

13.2 THE PHOSTRIP PROCESS AND NITROGEN REMOVAL.

The complete compatibility of nitrification and denitrification with the Bio-P process has long been confirmed by many studies.

The Verbundforschungsvorhaben (1996) confirmed that the same was true for the Phostrip Process. Nitrification and above all, denitrification are fundamental requirements for the Bio-P process.

One interesting aspect is the denitrification of the nitrates remaining in the recirculated sludge which are passed to the stripper. If the denitrification capacity of the pre-stripper is taken into account when calculating the necessary aeration tank volume according to ATV 131, the total NO_3-N load to be denitrified can be reduced by the quantity NO_3-Ne_{in} x Q_{side}.
Where:

NO_3-Ne_{in} = NO_3-N quantity in discharge
Q_{side} = Side stream quantity to stripper

This leads to savings in volume of the aerated sludge tank by several percent.

Another advantage of the Phostrip Process is the action of the stripper bed discharge which releases short-chain organic acids into the aeration tank(chiefly in the anoxic zone) which stabilises and enhances the denitrification.

The quantity of sludge anaerobically stored in the stripper(approx. 30-40% of total MLSS in the system) offers new possibilities to optimise the plant operation, especially the nitrification. In cases of a sudden increase in the incoming BOD load or when the MLSS is being washed out of the aeration tank by heavy rain, the MLSS can be raised in the aeration tank by increasing the output from the stripper bed outlet, whereby the optimum sludge age can be provided at any time.

13.3 INCREASED P-FEEDBACK FROM THE SURPLUS SLUDGE PRODUCED IN THE PHOSTRIP PROCESS.

The phosphates recirculated with the surplus sludge in Bio-P plants is small and from various studies can be taken as:

Pre-thickener: approx. 4% of influent load
Mechanical surplus sludge thickening:
approx. 1% of influent load
Fermenter, post-thickener, mechanical de-watering:
approx. 5-13% of influent load

Tests at Darmstadt Eberstadt show an average P-feedback from the surplus sludge of 10% and at ARA Schalchen of only 5%.

These values are within, or less than, the ranges obtained at plants operating only with precipitation.

14 CONTROL AND PROCESS STABILITY OF A PHOSTRIP PLANT.

14.1 PROCESS STABILITY.

The discharge values at existing plants are influenced only by:

- The MLSS load from stripper bed discharge.
- The NO_3-N concentration in the effluent.
- The MLSS quantity stored in the stripper tank.

Concentration fluctuations (including the P-load) in the influent have very little influence on the discharge concentrations.
This can be explained by the very high P-concentrations that are returned to the aeration tank with the stripper bed discharge and which dampen out variations in certain conditions at the intake:

- Hydraulic fluctuations.
- Variations in wastewater temperature.
- Variations in COD:PO_4-P ratio.
- Variations in COD:NH_4-N ratio.

Unlike the effect these variations have on a Mainstream process, it has been clearly demonstrated

(Verbundforschungsvorhaben 1996) that they have no effect on the P-elimination efficiency of the Phostrip Process.

Fig.7 shows graphs of typical concentrations in a Phostrip plant (Darmstadt Eberstadt)
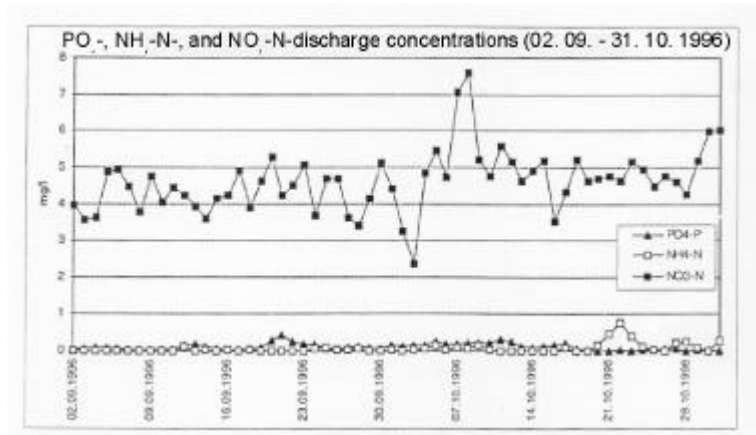
Figure 7 Optimised process operation - Graphs of PO4-P, NH4-N, NO3-N discharge concentrations 2.9.96-31.10.96.

This shows Phostrip plants produce very stable discharge values!

14.2 CONTROL OF A PHOSTRIP PLANT.

It is often said, unfairly, that the Phostrip process is complex and requires sophisticated control equipment.

The fact, in the entire process, only two parameters need to be controlled.
The MLSS quantity in the stripper and the pH value in the precipitation reactor or the quantity of precipitation agent.
All other factors remain constant following start-up and a short optimising period.

The most important variable in the process is the amount of sludge passed through the stripper, i.e. the anaerobic contact period.

In practice, this is controlled by an in-line MLSS probe together with a flow meter in the side-stream and the stripper bed discharge. The quantity of sludge discharged into the activated sludge tank is predefined and the quantity of sludge in the side-stream regulates itself automatically since the MLSS in and out of the stripper has to be constant.

In almost all Phostrip installations this discharge into the activated sludge tank is not altered, so in fact the whole process operates with constant settings, regardless of the influent. ***The Phostrip process places no additional workload on the workforce***.

A Phostrip plant does however require a more intensive start-up and optimising phase.

Very often Phostrip units are used to adjust and buffer the condition of the complete treatment cycle. Together with MLSS, flow in the Sidestream and the stripper bed outlet as parameters and the very large quantity of activated sludge stored in the stripper, any corrections to the sludge loading in the aeration tank can be quickly made by adjusting the output from the stripper bed. The P-elimination is hardly affected at all.

In case of an anticipated intake of toxic waste into the treatment cycle, the biocoenosis of the aeration tank can, at least partly, be stored for 1-2 days in the stripper as was demonstrated by the experiment carried out by the Verbundforschungsvorhaben (1996) at the treatment plant at Darmstadt Eberstadt.

A Phostrip installation can therefore act as a kind of safety cushion for the whole treatment works.

15 THE STRIPPER TANK AS A SURPLUS SLUDGE THICKENER.

The direct removal of surplus sludge from the stripper has been a success in all existing installations. MLSS values of 40 g/l have been achieved (ARA Hofkirchen) in the stripper bed discharge, making further de-watering or thickening before the sludge treatment unnecessary.

The Hofkirchen plant is now controlled entirely by the Phostrip unit. In other words, the MLSS of the bio-system is regulated by the stripper bed output, and the surplus sludge extracted directly from the stripper.

The stripper tank buffer also makes it possible to return sludge to the bio-system and so guarantee the optimal sludge age, regardless of temperature!

16 COST COMPARISONS – ECONOMICS OF THE PHOSTRIP SYSTEM

16.1 GENERAL

With the exception of the plant at Darmstadt Eberstadt, where the restrictions on effluent quality prevents virtually any other process from being considered, all existing, under construction or projected Phostrip installations have been compared economically with other processes according to guidelines laid down by LAWA (Länder Arbeitsgemeinschaft Wasser).

By considering all cost factors, running costs, investment, re-investment, etc., the Phostrip process turned out, in the long term, to be the most economic alternative, also when compared to precipitation.

16.2 COST COMPONENTS

16.2.1 Investment costs – Reinvestment costs

The absolute investment costs of a Phostrip installation depend naturally on the individual circumstances of each treatment plant, on the construction, the statutory discharge limits and the desired ease of operation and control. Often an existing sludge thickener can be utilised as a stripper. At all units so far installed, the cost of the Phostrip installation has been 5-10% of the cost of the complete treatment plant.

The amortisation periods used are as follows:

Pipework	50 years
Construction	40 years
Mechanical equipment	17 years
Electrical equipment	17 years
Control equipment	17 years

Over these periods, PAT GmbH also took into consideration:

Energy costs
Maintenance and repair costs
Personnel costs
Materials (Precipitating agents, grease, etc.)

As well as the investment and running costs, the following advantages can also be considered:

16.3 MONETARY BENEFITS OF A PHOSTRIP INSTALLATION.

Reduced aeration tank volume for the activated sludge

Depending on the required standards, the reduced production of inorganic surplus sludge, leads to 5- 35% (ATV 131) smaller aeration tanks, compared to a precipitation process.

Especially where there is a separate phosphate separation or recovery phase, this factor has a strong bearing on the economics, offering a reduction in investment costs. Above all, in the case of a necessary expansion of an existing treatment plant, it can be a deciding factor.

Savings in tank volume on account of the denitrification capacity of the pre-stripper are generally not taken into account, they are regarded as an additional reserve.

The improved sludge index (certainly less than 100ml/l) is usually not considered financially since it is often argued that this index improvement is also achieved by precipitation agents. The combination of savings on aerated tank volume and sludge index improvement, following the introduction of a Phostrip process, can render a further expansion of an existing treatment plant unnecessary.

16.3.1 Lower materials costs

Savings in material costs are the greatest factor in the economic comparison, the precipitating agent being the most significant.

16.3.2 Lower sludge handling costs

The cost difference compared to precipitation in the mainstream is calculated from the de-watering costs; conditioning agents, running costs for mechanical de-watering per kg MLSS and also storage and disposal costs.
If the stripper is also used as an waste sludge thickener or as pre-storage tank for sludge treatment then the saving in investment costs for such a tank can also be considered as a benefit.

Where there is a programme for the recovery of phosphate sludge and a marketing of the product, this is considered as a direct income.

16.4 NON-MONETARY ADVANTAGES

Other advantages of the Phostrip process not considered financially:

- No increase in the salt concentrations in the receiving waters
- No lowering of the acid capacity
- Denitrification support
- Lower heavy metal concentrations in surplus sludge
- Higher P-content in sludge for agricultural sludge spreading
- Micro-biological buffering and stabilisation of nitrification and de-nitrification

16.5 SUMMARY OF ECONOMIC CRITERIA FOR PHOSTRIP PROCESS

From the economic studies carried out so far in Austria, the following criteria have been identified:
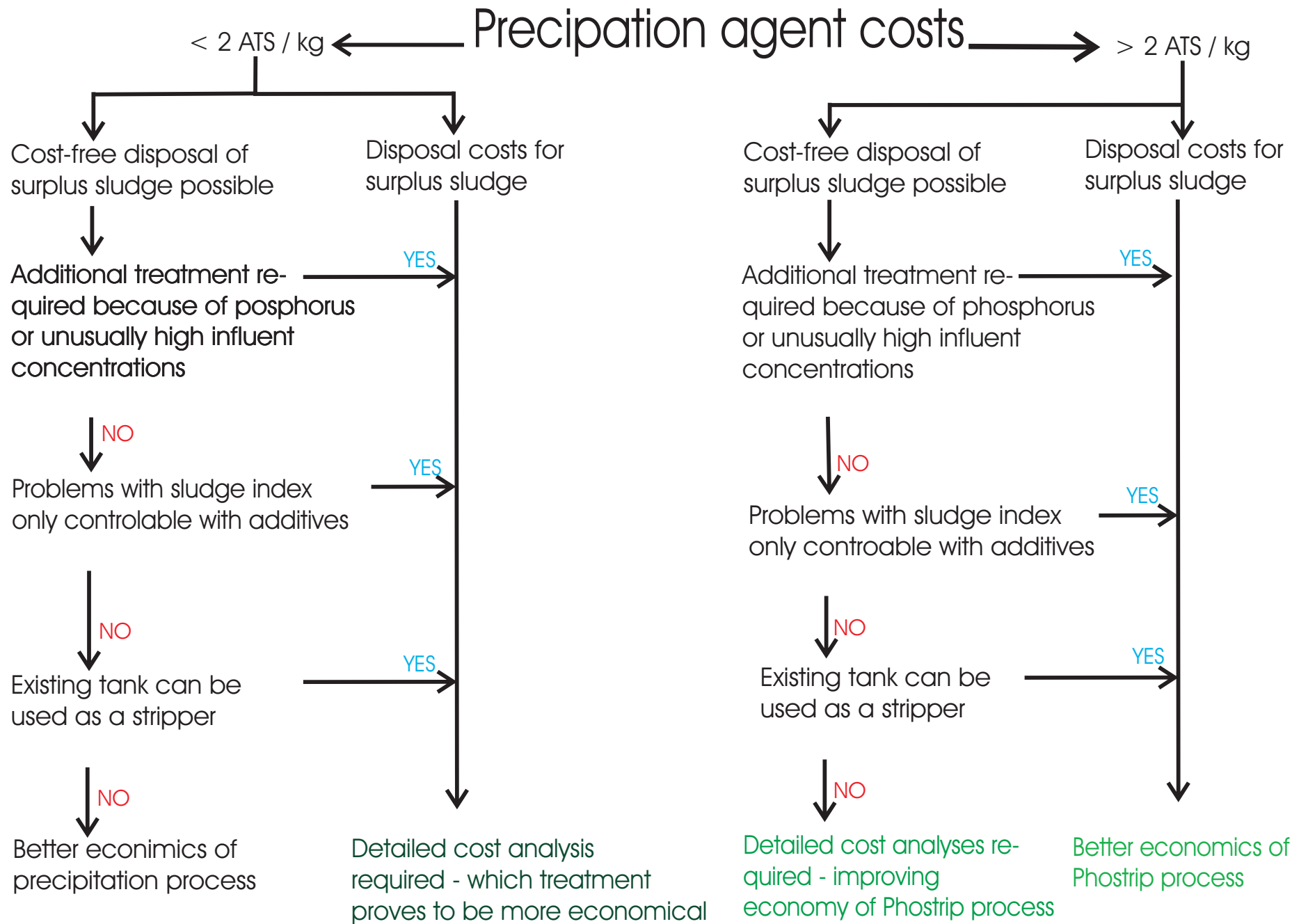See Fig 8.

Figure 8

17 EXAMPLES OF PHOSTRIP INSTALLATIONS

TREATMENT PLANT AT HOFKIRCHEN – REINHALTEVERBANDE MITTLERES TRATTNACHTAL (AUSTRIA)

Startup date 1997

Capacity 7,000 p.e.
Activated sludge plant with enhanced nutrient removal and simultaneous aerobic sludge digestion

Sludge treatment: Dewatering in centrifuge with discharge treated with lime, agricultural sludge spreading.

Stripper volume: 285 m^3 The stripper also serves as a waste sludge thickener and a storage tank for the dewatering centrifuge. This double function gives the Phostrip process an economic advantage.

Pre-stripper volume: 13 m^3.

Precipitation of the stripper overflow: Currently with commercial alkaline products. Saving in precipitation agents of 88% compared to precipitation process.

TREATMENT PLANT AT DARMSTADT EBERSTADT – SÜDHESSISCHE GAS UND WASSER AG (GERMANY).

Startup date 1992

Capacity 50,000 p.e.
Nitrifying and denitrifying activated sludge plant with anaerobic sludge digestion.

Sludge disposal: Dumping.

Stripper volume: 1910 m^3 As this was the first plant of its type in Europe, it is somewhat oversized. Of two stripper tanks constructed, only one is in use. The economics here were governed by the fact that a process was required that did not lower the acid capacity of the receiving water.

Pre-stripper volume: 44 m^3.

Precipitation of the stripper overflow: Originally with lime, currently with alkaline sodium aluminate. Savings in precipitating agent, 75%.

The plant is extensively documented in the Verbundforschungsvorhaben 1996.

CENTRAL TREATMENT PLANT DARMSTADT EBERSTADT – SÜDHESSISCHEN GAS UND WASSER AG (GERMANY).

Startup date 1997

Capacity 240,000 p.e.
Primary clarifier, activated sludge process with nitrification and denitrification.

Sludge treatment: Anaerobic digestion, surplus sludge recycled by own firm (mostly compost).

Stripper volume: 6385 m^3 Pre-stripper integrated into the stripper, internal recirculation via the pre-stripper.

Pre-stripper volume: 306 m^3.

Precipitation of the stripper overflow: With sodium aluminate, separation in phosphate separator through the addition of polymers and afterwards static dewatering of the product by centrifuge. Customers for the aluminium phosphates are being sought. Savings in precipitating agent, 70%.

A Phostrip installation in a plant of this size is always economical.

TREATMENT PLANT SCHALCHEN – RHV MATTIG HAINBACH (AUSTRIA)

Pilot plant on a technical scale, in use from 1994-1998

Capacity 30,000 p.e.
Primary clarifier, activated sludge process designed for nitrification only, separate anaerobic sludge digestion.

The primary clarifier tank (rectangular 540 m^3) was bypassed and used as a stripper.
A pre-thickener was utilised as a pre-stripper (120 m^3).
Precipitation was originally with lime but later abandoned. Nevertheless, the discharge level of 1mg/l P$_{tot}$ was maintained.
The running of this plant is documented in the masters thesis of Annegg (1996).

Expansion of Schalchen treatment works:

Construction begun 1998, startup end 1999.

Expansion Capacity 50,000 p.e.
The design objective was to increase the capacity of the treatment plant by a series of measures which would reduce the load to the activated sludge tank to such an extent that only an increase in the water level in the tank would be necessary to provide the extra capacity. The measures were:

- Reactivating the primary clarifier
- Construction of a Phostrip installation

- Construction of an ammonium stripping plant to reduce the nitrogen feedback from the surplus sludge treatment.

This scheme will reduce the original cost estimates for a conventional expansion of the plant from ATS 120 million to ATS 60 million.

Stripper volume: 500 m^3.

Pre-stripper volume: 100 m^3.

Precipitation of the stripper overflow: With lime, separate removal of calcium phosphates.

All valuable substances such as ammonium sulphate and calcium phosphate are recovered. Because of the excellent quality of the sludge with high phosphate content, the agricultural reuse of the sludge is encouraged.

TREATMENT PLANT WALLANG – RHV TRATTNACHTAL (AUSTRIA)

Construction begun 1998, planned startup 2000

Capacity currently 40,000 p.e. with targeted expansion capacity of 70,000 p.e.

Process concept: Primary clarifier, load relief of activated sludge process by the Phostrip process, raising of the water level in the activated sludge tank and improvements in the secondary clarification.

Sludge treatment: Anaerobic digestion and agricultural recycling

Stripper volume: 500 m^3.

Pre-stripper volume: 100 m^3.

Precipitation of stripper overflow: With commercial metal salts, separation in the primary clarifier.

The economics of the Phostrip system have been achieved through:

- The reduction in volume of the activated sludge tank.
- The improvement in the sludge index making an expansion of the secondary clarifier tank not necessary.
- Through the reduced costs of precipitation agents.

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