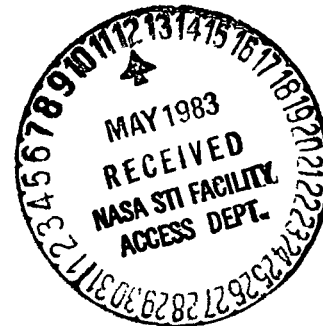


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ECONOMY OF PRECIPITATING AGENT APPLICATION
IN MUNICIPAL WASTEWATER TREATMENT FACILITIES

U. Neis, B. Geppert, H. H. Hahn and D. Gleisberg

Translation of "Wirtschaftlichkeit des Faellmit-
teleinsatzes in kommunalen Klaeranlagen", gwf-
wasser/abwasser, vol. 122, no. 6, 1981, pp. 242-250



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16. Abstract purification by precipitation in this study is not considered primarily as a means of phosphate removal but as a method for reduction of suspended solids BOD and COD. A dynamic calculation procedure is used to allow for exact determination of time dependent variation of costs. The results show that costs of wastewater treatment by precipitation may equal those of conventional primary clarification and secondary biological treatment (sludge load $B_{TS}=0.3$ kg/kg·d), especially with low-cost iron-II-salts in simultaneous precipitation and in larger plants (>20,000 PF). Cost advantages may be accrued in smaller plants by using the more expensive trivalent salts in pre-precipitation as compared to conventional low-load biological treatment ($B_{TS}=0.15$ kg/kg·d). This is due mainly to better effluent quality and, consequently, lower wastewater fees (Wastewater Discharge Act). If the precipitant is dosed temporarily only during periods of highest pollution; the savings can be about 5-10%.					
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U. Neis, B. Geppert, H. H. Hahn and D. Gleisberg

1. Objective of the Study

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The objective of this study is to establish the ways in which economic advantage and benefits could be expected to be obtained by application of precipitation and/or flocculation processes in municipal wastewater processing facilities. Purification by precipitation in this study is not considered primarily from the viewpoint of phosphate elimination, but rather as a method promoting reduction of solids (TS) BOD and COD. The aspect to be looked into in this context is whether municipal wastewater treatment plants using precipitation offer an economic advantage over those that do not make use of precipitation, or when they at least do not pose any significant economic disadvantage. Employment of operational (simple control of the process, stability under peak load) and ecological (removal of nutrients) effective measures can thus yield a benefit.

In dealing with wastewater processing, to include pre-sedimentation of sludge, this study does not take into consideration rainwater and sludge processing.

Post-precipitation has not been included in this study.

2. Operational Hypotheses

This study is based on the following theses:

a) Pre-precipitation makes the subsequent biological wastewater purification easier. This provides for

*Numbers in the margin indicate pagination in the foreign text.

--smaller dimensions of the biological stage, i.e., lower costs, or

--improved performance with unchanged dimensions of the biological stage, synonymous with reduced wastewater discharge.

b) Simultaneous precipitation using cost-effective precipitation agents (Fe-II salts) improves the purification effect and reduces wastewater discharge.

c) Conventional wastewater treatment facilities operating beyond their capacity become permanently sanitized through introduction of precipitation treatment.

d) Dosage of precipitation agents limited in time to correspond with peak loads reduces the total costs.

3. Treatment Systems

3.1 *System Selection and Dimensioning*

The below enumerated treatment systems provided the basis for computations:

a) Conventional mechanico-biological treatment (activated sludge process)

aa) Sludge load $B_{TS}=0.3$ kg BOD₅/kg TS·d
Spatial load $B_R=1.0$ kg BOD₅/m³·d

ab) Sludge load $B_{TS}=0.15$ kg BOD₅/kg TS·d
Spatial load $B_R=0.5$ kg BOD₅/m³·d

This variant is selected due to its higher reliability in regards to maintenance of the postulated processing parameters as is also the case in treatment by precipitation.

b) Precipitation treatment in a conventional system
 $B_{TS}=0.3$ kg BOD₅/kg TS·d

ba) Precipitation and strongly reduced volume of aeration tanks
 $B_R=5.0$ kg BOD₅/m³·d

bb) Pre-precipitation and aeration tank of normal dimensions
 $B_R = 1.0 \text{ kg BOD}_5/\text{m}^3 \cdot \text{d}$

bc) Simultaneous precipitation with unchanged biological stage
 $B_R = 1.0 \text{ kg BOD}_5/\text{m}^3 \cdot \text{d}$

The investment costs that were taken into consideration apply to the treatment system from the pre-settling tank to the sludge pre-thickener (Figure 1). Components which do not affect cost comparison, such as rakes and sand traps, are not included.

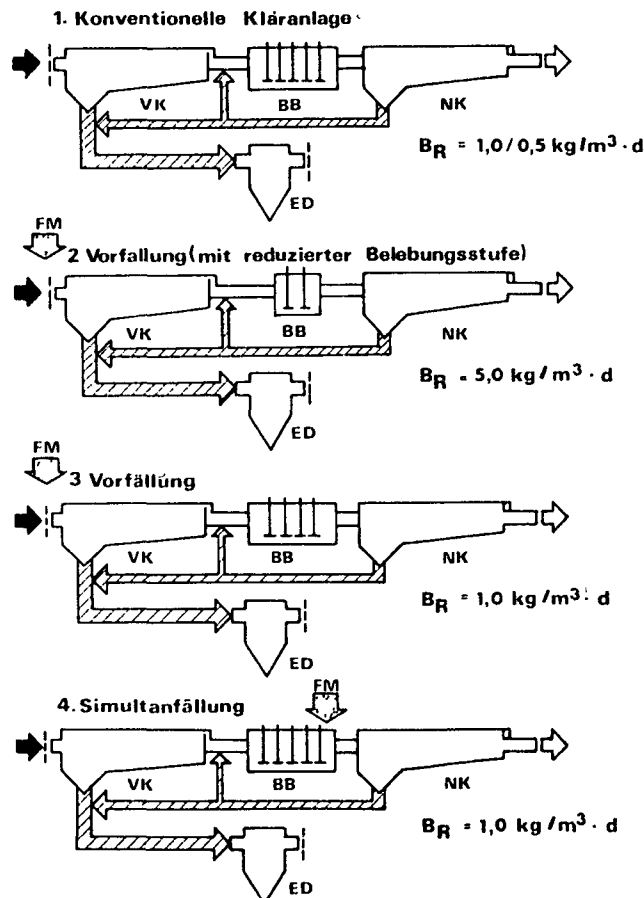


FIGURE 1. Selected Treatment Systems

Key: 1 - Conventional Wastewater Treatment Facility; 2 - Pre-precipitation (with reduced activation stage); 3 - Pre-precipitation; 4 - Simultaneous precipitation.

The considered treatment systems are classified into three size categories: 5,000, 20,000, 100,000 EGW (Table 1). Dimensioning of the structures was done according to ATV guidelines (1).

3.2 Performance Data

Increased reduction of COD and BOD contents in the pre-clarification stage can be expected to result from pre-precipitation. Consequently, a smaller biological stage need be built (see variant ba). In comparison to conventional pre-treatment through sedimentation (removal of approximately 25% of BOD), the following performance criteria have been established for pre-precipitation facilities (2 through 11): 50% COD and 75% BOD reduction.

TABLE 1. Dimensioning of Structures and Systems

Variant	B _R *)	Vorklarbecken 1 (m ³)			Belebungsbecken 2 (m ³)			Rücklaufschlamm 3 (m ³ /h)			O ₂ -Eintragsstg 4 (kW)			Nachklarbecken 5 (m ³)			Vordicketer 6 (m ³)			
		EGW	20000	100000	EGW	20000	100000	EGW	20000	100000	EGW	20000	100000	EGW	20000	100000	EGW	20000	100000	
Konv	aa	1,0	144	720	4320	225	900	4500	67,5	283	1406	10,4	41,7	208	280	1170	5760	10	40	200
	ab	0,5	144	720	4320	450	1800	9000	unverändert			13,1	52,1	261	unverändert			9,5	38	189
VF	ba	5,0	144	720	4320	15	60	300	unverändert			0,9	3,4	17,3	unverändert			15	62	313
	bb	1,0	144	720	4320	75	300	1500	unverändert			2,4	9,8	48,9	unverändert			15	62	313
SF	bc	1,0	144	720	4320	225	900	4500	unverändert	7		10,4	41,7	208	unverändert	7		10	40	200

*) (kg BSB₅/m³ d) VF = Vorfällung, SF = Simultanfällung

Key: 1 - Pre-clarification tank; 2 - activation tank; 3 - reflux sludge; 4 - O₂ aeration output; 5 - settling tank; 6 - pre-thickener.

The 50% elimination of COD was arrived at through literary refer-/244
ence data and through empirical values based on median addition of
0.6 mol of trivalent metal ions per m of wastewater, as shown in
Figure 2. Thus, precipitation agents with approximately 0.3 mol of
Me³⁺/100 g (e.g., AVR) would have to be added in a dose of 200 g/m³.

A 30% increase in the load of solids can be expected in the pri-
mary sludge (5, 6) with the use of precipitation. Assuming no change
in the concentration of solids in this mixed sludge in pre-precipita-
tion, it denotes a 30% increase in volume for the pre-thickener. No
increase in sludge volume occurs in simultaneous precipitation.

Determination of the process parameters is based on standard
values of the ATV manual (12), or is computed for simultaneous pre-
cipitation from overload of conventional plants (Table 2).

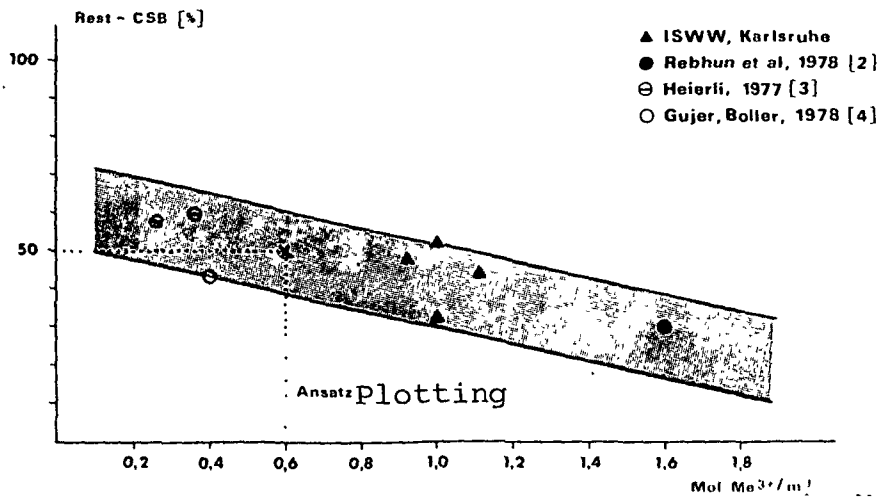


FIGURE 2. COD (Rest-CSB = Residual COD) Through Pre-Precipitation According to Various Sources

TABLE 2. Selected Performance Parameters of Individual Variants (medium daily effluent concentrations)¹

Variante	B _R ²⁾	BSB ₅ (mg/l)			CSB (mg/l)		
		FGW 5000	20000	100000	5000	20000	100000
Konv. da	1,0	20	20	20	90	90	90
ab	0,5 ³⁾	20	20	20	90	90	90
VF. ba	5,0	20	20	20	90	90	90
bb	1,0	12	12	12	60	60	60
SF. bc	1,0	6,7-20	5,5-16,4	4,8-14,4	40-90	36-77	34-69 ⁴⁾

- 1) According to ATV Manual, vol. II (12)
- 2) (kg BOD₅/m³ · d)
- 3) Smaller fluctuations in progress than in B_R=1.0
- 4) Computed according to overload for an extant conventional plant.

4. Cost Computations

The following types of costs are included in the computations:

Investment costs as a write-off

Operational costs

---material costs (without precipitation agents)

--energy costs

--personnel costs

Precipitation costs

Wastewater discharge

Costs of interest (capital costs).

4.1 Investment and Operational Costs

The investment costs I_{ges} for the individual structural elements are computed as a function of tank size on the basis of extensive own investigations (13) and with the use of coincident results /245 obtained by Hoffmann (14).

In analogy to Hoffmann's findings, first comes computation of operational costs for the conventional variant aa. Operational costs of other variants are arrived at by giving due consideration to the higher or lower output in regards to reflux sludge and oxygen aeration in the activation tank on the basis of the operational costs for variant aa.

4.1.1 Investment Costs

The write-off in year t is:

$$A_t = A_{bau} + A_{masch} \quad (1)$$

$$A_{bau} = \frac{\text{Investment structures}}{\text{Service life}} = \frac{I_{bau}}{t_{bau}} = \frac{I_{bau}}{30} \quad (2)$$

$$A_{masch} = \frac{\text{Investment machinery}}{\text{Service life}} = \frac{I_{masch}}{t_{masch}} = \frac{I_{masch}}{13} \quad (3)$$

4.1.2 Operational Costs

These are calculated as a function of total investment and EGW.

Operational costs in year t :

$$B_t = r \cdot I_{ges} = r \cdot (I_{bau} + I_{masch}) \quad (4)$$

wherein $r = 2.5 \text{ EGW}^{0.02864} (\%)$ acc. to Hoffmann (14)

<u>EGW</u>	<u>r (%)</u>
5,000	3.1906
20,000	3.3200
100,000	3.4765

4.2 Precipitation Costs

The computation program allows for determination of the annual total costs for precipitation facilities, whereby the used variables, e.g., the purchase price for precipitation chemicals, costs of transportation or costs of interest for tied up capital can be varied at

random. This program facilitates expedient computation of various effects, such as, e.g., changes in prices of precipitation agents and other factors.

4.3 Costs of Wastewater Discharge

Consideration of wastewater discharge offers a possibility for monetary assessment of the utilitarian value of improved discharges from the processing plant. Wastewater discharge is treated in these studies in analogy to the AbwAG Act and the 1st Water Pollution Management Regulations.

Assessment of damage units is measured in COD-concentration effluents at DM 40.- per damage unit. Halving of discharge while maintaining the minimum requirements is duly recognized.

4.4 Total Costs

The total costs are added up:

$$GAJ_t = B_t + F_t + ABG_t \quad (5)$$

F_t = costs of precipitation; ABG_t = wastewater discharge.

Taking into consideration general price increases of $p_I\%$ and a higher cost of precipitation agents by $p_F\%$ annually, makes the annual total expenditures

$$GAJ_t = B_t (1 + p_I/100)^{t-1} + F_t (1 + p_F/100)^{t-1} + ABG_t \quad (6)$$

The costs of interest in year t

$$ZKOSJ_t = \sum_{\tau=0}^{t-1} (GAJ_{\tau} \cdot (1 + p_K/100)^{t-\tau-1} \cdot p_K/100) \quad (7)$$

The costs occurring in year t then are

$$GESKOJ_t = A_t + GAJ_t + ZKOSJ_t \quad (8)$$

The total costs are computed for the duration of the planning period of 30 years by summation of the annual costs $GESKOJ_t$.

4.5 *Dynamic Computation of Economy of Operation*

Use of conventional static cost computation methods applied to the methods of physicochemical wastewater processing, which show a relatively high orientation toward materials, is connected with a high inaccuracy of results, because cost fluctuations cannot be reflected. They are given by fluctuations in the requisite processing performance that result from a varying specific load.

For that reason dynamic cost computation is resorted to. It reflects the chronological occurrence of costs as well as their varying level throughout the entire planning period.

The study uses dynamic concepts for the following three cases:

A) Regularly recurring fluctuations in water volume or pollution degree.

B) Inclusion of precipitation processing into a newly constructed conventional mechanico-biological processing plant with chronological development of volume or pollution load till the end of the planning period.

C) Temporary sanitizing of a currently fully operating or /246 overloaded processing plant through introduction of precipitation processing. Determination of the optimum investment time t_i for a new plant without precipitation.

5. Results

5.1 *Periodical Dosage of Precipitation Agents (Case A)*

Potential savings of precipitation agents could be achieved by only periodical operation of a pre-precipitation facility. This could be achieved by, e.g., adding precipitation agents only during daylight hours when the flow of wastewater is higher than the 24-hour average. The requisite control system is easy to install.

This mode of operation was simulated in several computer runs. The basis for it was provided by various predetermined daily progression

of wastewater volumes that were measured in the field or were found in technical literature as typical for various sizes of processing plants. Figure 3 shows an example of one such selected progress line for small and medium size cities. According to this sample, a preprecipitation facility for small cities should be operated only between 0900-1600 and 1800-2100 hours, i.e., during 40% of the day. However, it would process 65% of the daily occurring wastewater volume and load. The results of these computations appear in Table 3. These results show that savings of total costs for pre-precipitation systems can be attained on the order of 5 to 11% with the increasing size of the facility.

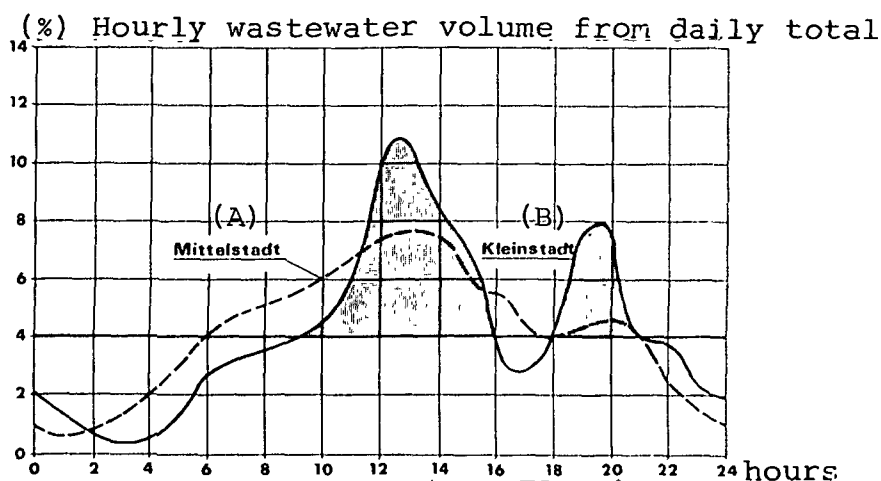


Figure 3. Typical Wastewater Progress Line for a Small Town and a Medium-Size City according to Poepel (17).
Key: (A) Medium-size city; (B) Small town.

TABLE 3. Potential Cost Savings Achieved Through Only Periodical Dosage of Precipitation Agents Between 0900-1600 and 1800-2100 hours

F.G.W. A Fallmittel (g/m ³)	5000			20 000			100 000		
	100	200	300	100	200	300	100	200	300
B Einsparung (%)									
C Fallungskosten	35	35	35	35	35	35	35	35	35
D Gesamtkosten	4,8	6,9	8,2	5,6	8,3	10,2	7,5	10,0	11,3

*) $p_k = 4\%$

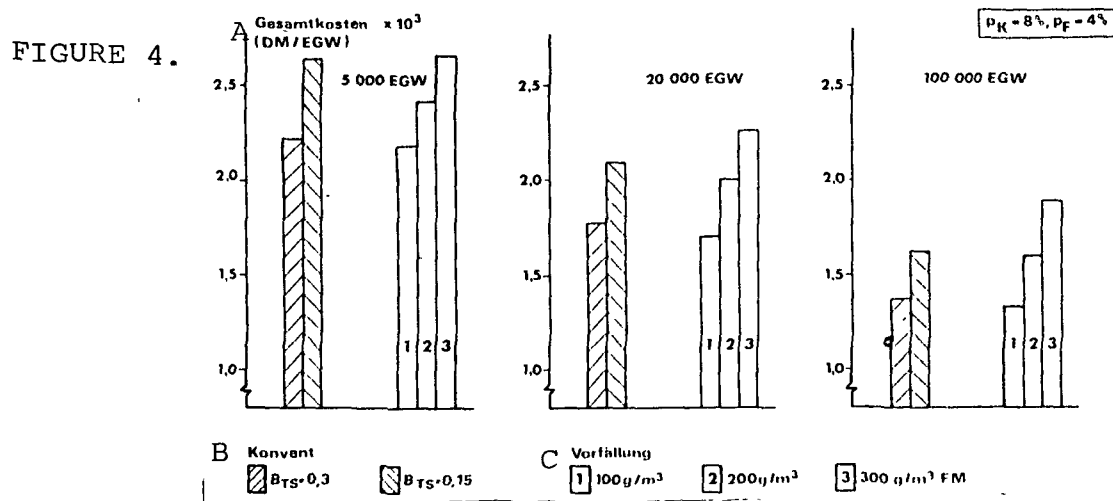
Key: A - Precipitation agent; B - Savings; C - Costs of precipitation;
D - Total costs.

5.2 Newly Constructed Processing Plants With and Without Precipitation Systems (Case B)

5.2.1 Pre-Precipitation

This section will provide an answer to the question under which conditions is integration of pre-precipitation into a newly constructed mechanico-biological wastewater processing plant worthwhile.

From the results (Figure 4, Table 4) we can arrive at some interesting conclusions:



Key: A - Total costs; B - Conventional; C - Pre-precipitation.
 FIGURE 4. Computed Total Costs for Conventional Activation Facilities (Variants aa, ab) and Facilities With Pre-precipitation (Variant bb). 150.- DM/t FM.

TABLE 4. Total Costs for Varying Types of Processing Plants in millions of DM¹

LGW	p_K (%)	A konventionell		B Vorfällung					
		B_{R^2} 1,0	0,5	Fällmittel	100	200	300	100	200
5000	0	1,4	1,6	1,5	2,0	2,4	1,6	2,1	2,5
	4	3,8	4,5	3,8	4,5	5,2	4,0	4,7	5,4
	8	11,1	13,2	10,3	11,5	12,7	10,9	12,1	13,3
20000	0	4,2	5,0	5,3	7,2	9,0	5,4	7,3	9,1
	4	12,0	14,3	12,7	15,7	18,7	12,9	16,0	18,9
	8	35,3	41,8	33,6	38,9	44,2	34,2	39,6	44,9
100000	0	16,0	19,1	22,7	32,6	42,4	22,5	32,3	42,1
	4	46,5	55,3	53,1	68,9	84,7	51,8	67,6	83,4
	8	136,8	162,5	137,2	165,2	193,0	132,9	160,9	188,8

¹ Cost of precipitation agent: DM 150.-/t. Price increase $p_F = 4\%$.
² kg BOD₅/m³ · d

Key: A - Conventional; B - Pre-precipitation.

The calculated interest rate dominates the absolute total costs. Relatively considered, there appears to be a slight tendency in favor of the precipitation variant, as long as the interest rate exceeds the annual rate of price increase.

At a constant purchase price for precipitation agents (the figure used: DM 150.-/ton) the total costs of the precipitation variant are decisively influenced by the concentration of the agents.

With dosage of chemicals at approximately 150 g/m³ (here 0.45 mol Me³⁺/m³) the break-even point can be achieved with a conventional low-output installation ($B_{TS} = 0.15$, variant ab).

Pre-precipitation systems tend to offer cost advantages mainly in the case of small and median installations. This is due, on the one hand, to lower consumption of precipitation agents because of the low specific wastewater volume. On the other hand, the specific construction costs for small conventional installations are relatively high in comparison to those for large installations (construction cost depression). -247

Cost differences between the precipitation variants ba and bb are minimal. That means that the considerably reduced construction volume of the variant ba finds no expression. Through more favorable progression parameters of the larger installation bb, there appears a slight investment cost advantage due to saved wastewater discharge over ba that increases with the size of the installation.

In comparison to conventional single-stage activated sludge installations (aa, ab) savings in construction volume offer no advantage. The investment cost advantages are compensated for in this particular comparison by the costs of precipitation.

Only a narrow scope is provided for making changes in the price of precipitation agents, as only trivalent metallic salts can be used with success in pre-precipitation. A current market analysis shows that the lower price threshold for trivalent metallic salts at the present is on the order of 130.- DM/t (from the factory).

5.2.2 Simultaneous Precipitation

In comparison to pre-precipitation, simultaneous precipitation plants offer the economic advantage of using the cheaper bivalent iron salts. In the activation tank the bivalent iron is oxidized into the more effective trivalent iron by aeration. The following groups of precipitation agents are generally available:

--wet iron-II-sulphate heptahydrate (green salt, waste product) at approximately DM 10.-/t;

--dry iron-II-sulphate heptahydrate (produced from green salt, suitable for spraying) at approximately DM 80.-/t;

--iron-III and aluminum salt solutions (also for pre- and post-precipitation) at approximately DM 130.-/t up to DM 150.-/t;

--dry trivalent precipitation chemicals (also for pre- and post-precipitation) at approximately DM 150.-/t up to DM 200.-/t.

Dry iron-II salts can be used in conventional dry-dosage systems. On the other hand, the wet iron-II-sulphate calls for an additional dissolving station which must be included in the calculations.

Empirical findings show that at identical amounts of precipitation agents in simultaneous precipitation as compared to pre- /248 precipitation the discharge from the processing plant will be at least equivalent.

Due to better sedimentation behavior of solids simultaneous precipitation offers the possibility of using settling tanks of smaller dimensions, a fact which due to operational safety reasons was not included into the calculations. No assumptions are offered in regards to any effects on preliminary purification in comparison to conventional methods.

The following results are arrived at on the basis of simultaneous precipitation in conventionally dimensioned activation tanks with a sludge load of $B_{TS} = 0.3 \text{ kg BOD}_5/\text{kg TS} \cdot \text{d}$ (Figure 5).

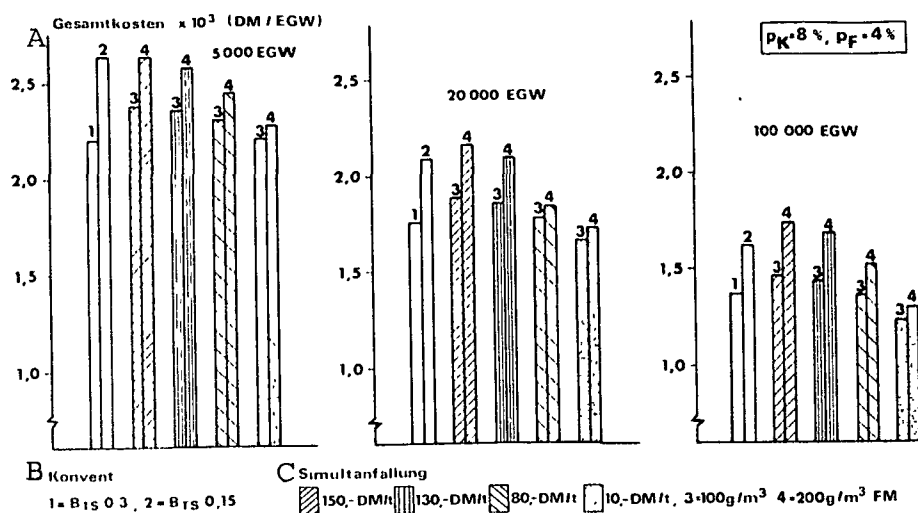


FIGURE 5. Dynamic Computation of the Economy of Operation of New Installations With/Without Simultaneous Precipitation. Key: A - Total costs; B - Conventional; C - Simultaneous precipitation.

It turns out that installations with simultaneous precipitation can also be cheaper than activated sludge installations with $B_{TS} = 0.3$, because of savings in wastewater discharge. However, this applies only to larger installations ($>20,000$ EGW) and in the case that use can be made of favorably priced iron-II precipitation agents at DM 10.- per ton. In comparison to low output installations with $B_{TS} = 0.15$, simultaneous precipitation installations are always cheaper when the difference in precipitation agent prices is below a consumption level of 200 g/m^3 and/or interest on capital exceeds $p_K 4\%$.

A comparison of costs for pre- and simultaneous precipitation is shown in Figure 6. From the columnar diagrams of that figure can be derived the tendency that simultaneous precipitation with more cost-effective precipitation agents offers significant economic advantages over pre-precipitation using expensive precipitation agents, particularly at large processing plants (high volume of consumption). In comparing these results it should be kept in mind that simultaneous precipitation mostly calls for smaller concentrations of precipitation agents than does pre-precipitation.

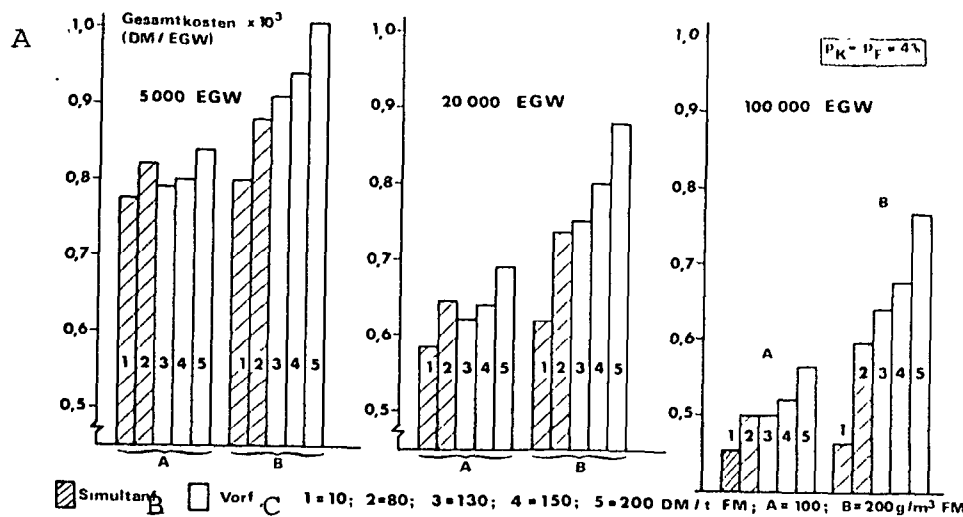


FIGURE 6. Comparison of Total Costs of Pre- and Simultaneous Precipitation Installations
 Key A - Total costs; B - Simultaneous precipitation; C - Pre-precipitation.

5.2.3 Relative Shares of Cost Types

Figure 7 shows the outstanding importance of interest costs for the case when increases in the rates of interest and prices for precipitation agents are projected with 4%. These take up approximately 45% of total costs. Next in importance among cost factors are the costs of precipitation agents. In the presented example their share ranges between 15 and 25% depending on the required dosage. This share would be lower for simultaneous precipitation using cheaper precipitation agents. Write-offs and operational costs range between 10 and 15%, wastewater discharge between 5 and 10%.

Additional computations have unequivocally confirmed that interest and precipitation costs represent the decisive cost items. Write-offs and operational costs show only a minimal fluctuation in their respective shares. Changes in the parameters interest rate, price of construction and that of precipitation agents wield a decisive influence on the relative shares of interest and precipitation in costs.

A failure to include wastewater discharge would primarily affect the relative share of precipitation costs. In Figure 7 they

show, in the example provided there, a range fluctuating between 22 and 36%.

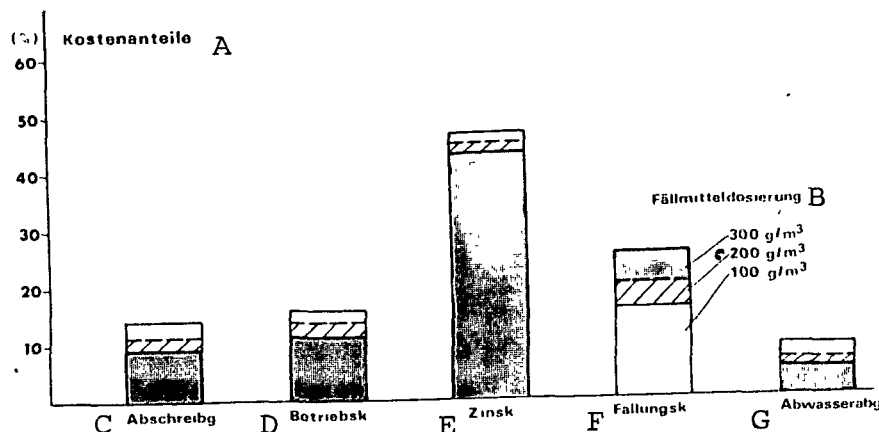


FIGURE 7. Shares of Individual Cost Types in Total Costs for a Planning Period of 30 Years; Pre-Precipitation (variant bb) Example: 20,000 EGW; interest rate p_K 4%; price increases in precipitation agents p_I 4%; price of precipitation agents 150.- DM/t; processing plant runoff of BOD_5 12 mg/l, COD 60 mg/l.

Key: A - Cost share; B - Dosage of precipitation agents; C - Write-offs; D - Operational costs; E - Cost of interest; F - Precipitation costs; G - Wastewater discharge.

The factor precipitation costs is the most sensible among the mentioned individual factors. The computation results in Table 5 impressively emphasize how much the percentual share of precipitation costs in total costs depends on the selection of the parameters interest rate and price increases. The results are to be interpreted as indicating that with increasing interest rates the use of precipitation system offers more advantage.

5.3 Temporary Upgrading Through Precipitation Systems (Case C)

This section of the study will examine whether it is economically feasible to upgrade processing plant that currently operate at full capacity through installation of pre- or simultaneous precipitation systems.

It is predicted that with future increases in wastewater volumes the extant processing plants will increasingly become subject to overload resulting in ever increasing concentrations of BOD_5 and COD.

Table 5. Share of Precipitation Agents Cost in Total Costs*
In Percentages.

Kapital-Zinssatz A p_K (%)	Preissteigerung f. allm. Mittel p_f B		
	0	4	8 (%)
0	36,1	52,5	70,0
2	23,6	36,5	52,8
4	14,9	24,4	38,1
6	9,3	15,8	26,3
8	5,7	10,0	17,6
10	3,5	6,25	11,5

*Installation with precipitation; $B_R = 1.0$ (kg BOD₅/m³ · d);
20,000 EGW; 200 g/m³ FM; DM 150.-/t FM; including wastewater
discharge.

Key: A - Capital interest rate; B - Increases in the price of pre-
cipitation agents.

Upgrading can be implemented by introduction of pre-precipitation with trivalent as well as simultaneous precipitation with bivalent salts, to avoid the need for expansion or new construction of a larger conventional plant. These measures leave open the option to, e.g., see what future technical development will bring or to wait for changes in official requirements on quality of processing.

From the viewpoint of operational economy these tasks involve determination of the optimum time for investment in expanding the processing facility. The determinant factors then become: the interest rate p_K , increases in construction costs p_{bau} , price of precipitation agents and increases in the latter p_f .

To verify the effects of not only the above enumerated factors, but also those of the computation method itself, dynamic nominal value computations are followed up by additional computations according to the present value method (capital value method). However, a shortcoming of the latter method is that it does not compute the true sums that will be encountered in the planning period, but only the amounts with interest rates scaled down to the present value. On the other hand, the nominal value method provides a clear picture of the actual amounts of money which will be involved after inclusion of all the factors, such as interest rate, price increases (inflation), etc.

The great number of carried out computations and sensitivity analyses shows that the subsequently explained findings have a tendency to crop up independently of the computation method.

The obtained resultant curves (Figure 8) reflect the total costs that apply to various chronological points in the construction of a wastewater processing facility. They are constituted by:

- precipitation costs from time point = 0 to time point = , the point of time when the facility is built;
- operational costs for the entire planning period of 30 yrs
- investment costs for construction of the processing facility at time point = ;
- write-off of the new facility from time point = till the end of the planning period = 30;
- wastewater discharge throughout the entire planning period.

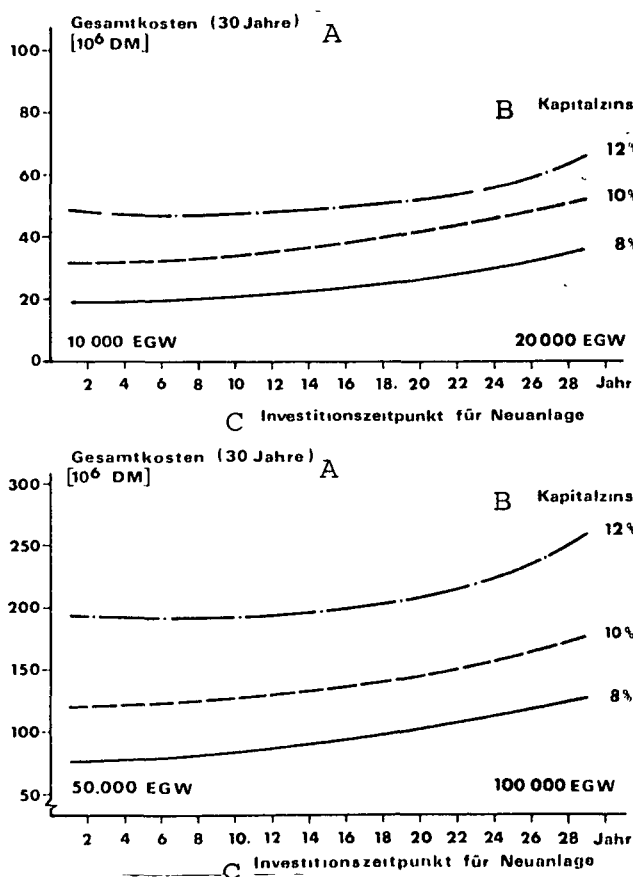


FIGURE 8. Determination of the Optimum Timing for Investment Into a New Conventional Wastewater Treatment Facility, Upgraded up to Then by Simultaneous Precipitation.
 Key: A - Total costs (30 years); B - Capital interest; C - Time for investment in a new plant.

The construction of a wastewater treatment plant is always laid out to coincide with the predicted EGW value at the end of the

planning period, i.e., specifically, when today 10,000 EGW or 50,000 EGW are in operation, plans are made to construct an additional 10,000 or 50,000 EGW.

(An example of computing assumptions. Precipitation agents: consumption 100 g/m^3 , price 80.- DM/t; increases: prices of precipitation agents $p_f = 4\%$, construction costs $p_{\text{bau}} = 6\%$, operational costs $p_B = 8\%$.)

The later the construction projects are contemplated, the higher total costs they incur (rising curves). The cost curves (in Figure 8) progress in the first third, i.e., for an investment timing within the first 10 years, with relative flatness, but start rising steeper later on.

Sensitivity analyses of all the presented data reveal the following tendencies:

--Temporary upgrading by means of precipitation processing can be recommended from the viewpoint of operational economy for a short to medium range (not to exceed 15 years). Over longer periods of time it leads, with inclusion of a later construction of another facility, to ever higher total costs.

--Times when high capital interest rates ($p_K = 12\%$) prevail are favorable for temporary upgrading through precipitation systems.

--If short or medium-term development of construction prices can be expected to remain moderate or even stagnant ($p_{\text{bau}} < 4\%$), the conditions are favorable for postponing the construction of a plant to a later point in time and using in the interim simultaneous precipitation with cost-effective precipitation agents at a dosage of below 150 g/m^3 .

6. Assessment of Results

The concentrations of precipitation agents ($100\text{--}300 \text{ g/m}^3$) used in the computations fall into the range of dosages used for phosphate precipitation in practice. The diagram in Figure 2 shows that the leeway for dosage to achieve a 50% elimination of COD through precipitation

is more than adequate and, thus, is theoretically the reliability at deviations from the used median value of $0.6 \text{ mol Me}^{3+}/\text{m}$ (abt 200 g/m^3).

The used concentrations of precipitation agents show promising effects on providing a buffer against peak loads and on damping the fluctuations in discharge as well as in P-elimination rates. These effects as well as additional elimination effects (e.g., heavy metals) show that wastewater processing through precipitation offers advantages over the conventional method at identical costs.

Authors:

Dr. Engr. Uwe Neis, Chief engineer at the Institute for Residential Water Management, University of Karlsruhe, Am Fasanengarten, 7500 Karlsruhe I.

Econ. Engr. Bernhard Geppert, Scientist at the Institute for Residential Water Management, University of Karlsruhe, Am Fasanengarten, 7500 Karlsruhe I.

Prof. Hermann H. Hahn, PhD, Head of the Institute for Residential Water Management, University of Karlsruhe, Am Fasanengarten, 7500 Karlsruhe I.

Dietrich Gleisberg, Dr Nat Sci, Hoechst, Ltd., Plant Knapsack, Application techniques department, Industriestrasse, 5030 Huerth-Knapsack.

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REFERENCES

1. ATV Worksheet A 131, Draft (1979).
2. Rebhun, M., Narkis, N. and C. Sheindorf, "Combination of Physico-chemical and Biological Processes for Wastewater Treatment and Reuse", Prog. Wat. Techn. vol. 112, no. 10, pp 173/184, Pergamon Press, London 1978.
3. Heierli, R., "Potentials for Improving the Performance of Wastewater Processing Plants", Gas-Wasser-Abwasser vol. 57, pp 42/47 1977.
4. Gujer, W. and M. Boller, "Effects of Chemical Flocculation and of Precipitation on the Activated Sludge Process", Veroeffentlichungen des Institutes fuer Siedlungswasserwirtschaft, no. 20, 6/1-36, University of Karlsruhe 1979.
5. Bischofsberger, W. et al., "Use of Precipitation Processes for Improving the Performance of Biological Installations", Berichte aus Wasserguetewirtschaft und Gesundheitsingenieurwesen, no. 13, Munich 1976.
6. Gleisberg, D., "Phosphate Precipitation in Wastewater Processing", Umwelt no. 1, pp 73/82, 1980.
7. Strauss, R., "Chemical Precipitation for Improving the Performance of a Drip Filtering Installation", Wasser, Luft, Betrieb no. 3, pp 2-3, 1976.
8. Ulmgren, L., "Experiences and Results from Chemical Precipitation of Domestic Waste Water in Full Scale Plants", Proc. 7th IAWPR Conference, Paris (1974), pp 409-416, Pergamon Press, London.
9. Klaentschi, K., "Precipitation and Flocculation to Improve the Performance of Wastewater Processing Plants", Gas-Wasser-Abwasser vol. 57, no. 1, pp 48-49, 1977.
10. Rebhun, M., Narkis, N. and R. Offer, "Physico-chemical Treatment of Raw Wastewater", Proc. 7th IAWPR Conf., Paris 1974, pp 401-408, Pergamon Press, London.
11. Gleisberg, D. and G. Sorbe, "Phosphates in the Environment", Chemie fuer Labor und Betrieb no. 28, pp 308-312, 1977.
12. ATV, "Textbook and Manual of Wastewater Processing", Vol. 11, W. Ernst & Son, Berlin 1975.
13. Neis, U., Hahn, H., Geppert, B. and D. Kortebein, "Study and Cost Comparison for Extensive Wastewater Treatment", Final report on Research Project 1020402, Federal Environmental Bureau, 1980.
14. Hoffmann, J., "Acquisition, Organization and Use of Data Regarding the State-of-the-Art in Wastewater Treatment Processes, Dimensioning and Costs", GWA vol. 33, Aachen 1979.

15. Official AfA Tables: Ammortization for Wear and Tear. Federal Ministry of Finance, 1977.
16. Krimmelbein, H., "Comparison of Operational Costs for Various Processes in Municipal Wastewater Treatment", Follow-up study at the Institute for Residential Water Management, University of Karlsruhe 1980.
17. Poepel, F. (publ.), "Textbook for Wastewater Treatment and Protection of Water Resources", Deutscher Fachschriftenverlang, Wiesbaden.