

## Tests carried out at the Jona Wastewater Purification Plant

*K. Wuhrmann and H. Leidner*

Between July 1969 and the end of April 1971 the EAWAG carried out extensive tests at the wastewater purification plant of Jona.

The Jona plant is the first in Switzerland to dispose of all three stages of wastewater treatment, which can be broken down as follows:

- 1) Mechanical primary sedimentation (screen, degritter, aerated oil separator, primary sedimentation tank)
- 2) Activated sludge stage (combined tank of the Aero-accelerator type, Lurgi AG)
- 3) Subsequent chemical precipitation for P elimination (post precipitation) (Cyclator type, Lurgi AG)

In the choice of a sludge treatment method, aerobic sludge stabilization was justifiably preferred to conventional digestion, as it offers the advantage that the excess sludge, which accumulates as a result of subsequent precipitation, can be used as a conditioning agent to dewater the „organic“ sludges in the filter press.

Some 4000 inhabitants were serviced by the wastewater purification plant during testing.

The testing periods were broken down into smaller units of time, the length of which was determined by the duration of the tertiary stage of treatment under the various testing variables. Independent variables were set for the individual testing objects. The minimum observation period for plant operation under a particular testing variable was four weeks. More important tests, however, lasted considerably longer and, in the case of stabilization and post precipitation, were repeated after long intervals of time.

### Testing variables

Indicated below are the values anticipated by the program and used as a criterion for determining the units of time for each test run.

### Post precipitation

- Lime precipitation at a pH of 10.5 to 11 with 1 mg Fe (III)/l used as a flocculant
- Lime precipitation at a pH of 10.5 to 11 with polyelectrolyte used as a flocculant
- Lime Fe (III) precipitation with 10 mg Fe (III)/l and a lime additive until a pH of 8.8 to 9 is reached in the precipitation chamber.

### Simultaneous precipitation

- Fe (III) used; dosing until the effluent has a total P content of 0.5 mg P/l.

### Sludge stabilization

Two temperature scales: „summer“ and „winter“ periods

### Sludge conditioning

- using lime and Fe (III) as recommended by Lurgi
- using sludge from post precipitation, possibly supplemented with lime and Fe (III).

### Sludge pressing

- pressing the stabilized, conditioned organic sludge alone
- pressing the sludge from subsequent precipitation
- pressing a mixture of the sludge from stabilization and post precipitation.

Table 1 gives a compilation of the main results and the actual values of the variables for all testing units. It shows that among the processes for post precipitation, only those using lime precipitation and flocculation with Fe (III) or combined lime Fe (III) precipitation were effective enough to produce the desired effluent concentration. Post precipitation with Fe (III) alone or Ca (OH)<sub>2</sub> precipitation with flocculation by means of polyelectrolyte proved unsatisfactory. Although this might seem surprising particularly for the latter process, it was found that the polyelectrolyte was adsorbed to the precipitated

CaCO<sub>3</sub>, hampering the growth of apatite and the adsorption of further compounds to a considerable extent. The insufficient efficiency of Fe (III) precipitation, which roughly corresponded to that of simultaneous precipitation, is also interesting. It must be concluded that, as in the case of post precipitation, the organic matter in the wastewater considerably impairs the adsorption capacity of the precipitated Fe (OH)<sub>3</sub>.

The unsatisfactory effluent quality with respect to P concentration during simultaneous precipitation that resulted despite the generous Fe (III) dose of 19.2 mg/l was noted with surprise. This finding must, however, be accepted as valid for the process since no technical defects in the plant were found.

The tests carried out on sludge stabilization under different testing variables (temperature, sludge concentration, O<sub>2</sub> input, mixing) revealed that no indication as to characteristic changes to be expected during stabilization could be inferred from the chemical composition of the solid matter in sludge. On the other hand, the observations showed that a correlation between stabilization variables and effects could be found on the basis of sludge water properties. Sludge concentration, O<sub>2</sub> input, mixing as well as the speed with which oxygen is distributed to all points in the stabilization tank are decisive factors for effective stabilization. Experience has shown that the sludge concentration should not exceed 20g DS/l, and the O<sub>2</sub> concentration should be about 3 mg O<sub>2</sub>/l (table 2).

A good solution to the problem of sludge dewatering lies in the use of a filter press, which is safe and easy to operate and brings regular results (less than 70% water content of the end product, less than 5% solid matter recycled to the plant for treatment). The sludge from subsequent precipitation that accumulates during the various processes of P elimination could be left to dewater without subsequent conditioning. The effectively „stabilized“ organic sludge could be thickened and

easily dewatered after conditioning with lime and Fe (III). From the economic and operational point of view, the most

advantageous conditioning method was to mix the „stabilized“, organic sludge with sludge from post precipita-

tion without adding any further chemicals: this mixture is the easiest to de-water.

Table 1: P elimination

System	Test Number	Dose		PE** mg/l	pH in reactor	Primary effluent		Final effluent			
		Ca (OH) <sub>2</sub> mg/l	Fe <sup>3+</sup> mg/l			ortho-P mg P/l	total P mg P/l	ortho-P mg P/l	total P mg P/l	total P %elim.*	
Post precipitation	1	79,4	7,6		8,9	3,4	5,3	0,59	0,79	85,0	220 days 50 samplings
	6	95,7	11,1		8,9	2,5	4,1	0,73	0,94	77,1	
	7	98,2	9,5		8,8	3,5	5,3	0,58	0,78	85,4	
	Mean								0,81	82,5	
	2	173,2	1,4		10,8	6,4	9,6	0,42	0,88	91,0	123 days 30 samplings
	8	132,3	0,9		10,6	4,7	7,9	0,24	0,57	92,8	
	Mean								<b>0,72</b>	<b>91,9</b>	
	3	183,0			10,7	3,8	5,6	1,34	1,82	67,5	
	5,9A		8,2/8,7	0,55	7,3/7,1	3,5	5,5	1,50	2,05	62,7	
9B		13,7		6,8	4,6	7,3	0,85	1,31	82,1		
Simult.-precipit.	10A/B		19,2		7,1	3,3	6,6	0,92	<b>1,84</b>	<b>71,2</b>	23 samplings

\* Calculated on the basis of concentrations

\*\*PE = Polyelectrolyte

Table 2: Sludge stabilization (Composition of the sludge water)

No.	Stabilizer				Sludge water (after sludge sedimentation) mg/l						Odor patterns during thickening
	Conc. g DS/l	Temp. °C	O <sub>2</sub> mg/l	Det. t days	org.C	org.N	NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	COD	BOD <sub>5</sub>	
1	60,7	16,9	1	9,7	356	67	0,5	40	1473	463	rapid odor development
7	20,9	17,5	1,5	6,3	41	15	1,4	5,7	174	51	remains "fresh"
2	58,7	13,4	1,9	6,6	349	76	2,3	19	1571	648	rapid odor development
8	9,7	12,6	3,9	5,6	34	9	9,6	1,3	101	20	remains "fresh"

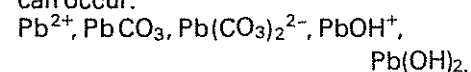
## Pb (II)-Species in Natural Waters

by Halka Bilinski and Werner Stumm

The rate of release of lead exceeds the rate of natural circulation. Approximately 1 million tons of Pb is introduced per year into the geosphere. Approximately 75% of this quantity enters the waters. In order to understand the distribution of lead in natural waters (sedimentation, adsorption, association with suspended materials, incorporation into the food chain) and its possible toxicity, information on the forms of occurrence of Pb in dissolved and solid phases is necessary.

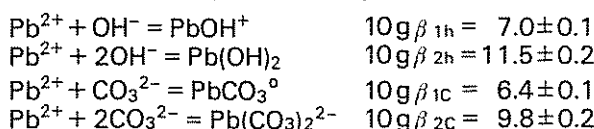
With the help of anodic stripping (inverse voltammetry) using hanging drop mercury electrodes, the speciation of lead(II) in dependence of solution variables (pH, alkalinity, organic ligands) has been investigated. Because of its great sensitivity, inverse voltammetry permits to investigate the solution behavior in the pH range of natural waters without precipitating of the solid phases.

In natural waters, the following species can occur:

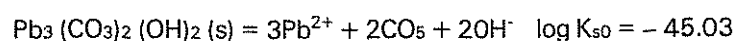


The stability of these complexes has been determined by observing the shift

in peak potential observed with increasing ligand concentration (figure 1). The following stability constants have been determined (25°C, I = 0.1):



With these constants a representative distribution of Pb(II)-species can be calculated (figure 2). Obviously in most natural waters the carbonate lead complex, PbCO<sub>3</sub>, will be the most prevalent species. This has to be considered in evaluating the solubility of PbCO<sub>3</sub> (s) and Pb<sub>3</sub>(CO<sub>3</sub>)<sub>2</sub>(OH)<sub>2</sub> (s). Tentative determinations on the solubility of lead carbonate have given the following result (25°C, I = 0.1):



Hence, a solution that is 10<sup>-3</sup> M in total carbonate gives within the pH range 7–9 a total lead solubility of ca. 10<sup>-6</sup> M, the predominant species being PbCO<sub>3</sub><sup>0</sup>; free lead ions predominate at pH values be-

low 6.5; anionic lead complexes prevail at pH values above 9.3.

In natural waters, most of the available

lead(II) is associated with suspended materials. Among the Pb(II)-species, the Pb(OH)<sub>2</sub> and the PbCO<sub>3</sub>-species are very strongly adsorbed at interphases. Figure 3 gives some data on the adsorbability of PbCO<sub>3</sub>; under similar conditions, i.e. solutions that do not contain CO<sub>3</sub><sup>2-</sup>, Pb<sup>2+</sup>-species are not adsorbed to interphases to any significant extent.

mean N:P ratio in flowing pre-alpine waters varies from 20 to 200:1, while the figure for Central Switzerland is 60 to 900:1. In Switzerland the tertiary stage of wastewater purification, that is, the elimination of phosphates, is stipulated by law in the catchment area of lakes. Hence the N:P ratio in the drainage area of lakes will never drop below 20:1. Given balanced algal growth, the nutrients phosphorus and nitrogen are assimilated by these algae in a 7:1 ratio by weight; consequently algal growth in such waters will be hampered by the phosphorus and not the nitrogen supply.

Although excessively high nitrate concentrations can be a threat to our drinking water supply, our struggle to curb eutrophication must be oriented toward reducing phosphorus losses in the soil however insignificant they may be from the economic point of view.

The tolerable and dangerous phosphorus loads from the drainage area of 28 Swiss lakes with a surface area of over 1 km<sup>2</sup> were calculated on the basis of

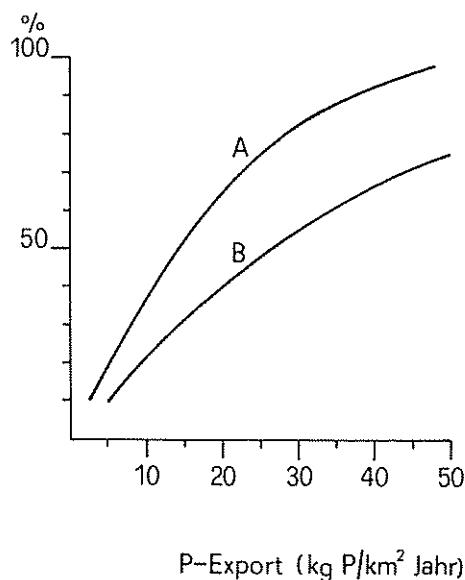


Figure 2

*Degree of eutrophication in Swiss lakes with more than 1 km<sup>2</sup> in surface area in relation to the phosphorus loads from drainage areas.*

Vollenweider's (15) tolerance values for phosphorus in lakes. Figure 2 shows clearly that intensive land cultivation with yearly phosphorus losses of 35 to 70 kg P/km<sup>2</sup> (see fig. 1) is irreconcilable with an oligotrophic lake. Even with an annual phosphorus loss of as little as 35 kg P/km<sup>2</sup>, 90% of our lakes would be endangered; this means that only 10% would still be oligotrophic, 30% mesotrophic and 60% eutrophic. Fortunately, however, the catchment area of none of our larger lakes is used entirely for agricultural purposes. Parts are always wooded, while others are unproductive (glaciers, rocks).

Yet phosphorus losses from the soil are only one source of the phosphorus load in lakes. If 3 g P/capita per day are reckoned, the following phosphorus loads, relative to the population density, are added by municipal wastewaters.

A = Percentage of endangered lakes (mesotrophic and eutrophic)  
B = percentage of eutrophic lakes

Table 1: *Phosphorus accumulation (kg P/km<sup>2</sup> year and based on specific surface area) in relation to the population density and*

*the effectiveness of the wastewater purification plant*

Population density Inhabitants/km <sup>2</sup>	Mech. and biol. purification P elimination: 30%	Tertiary treatment	
		85%	95%
10	7.7	1.7	0.6
50	38.5	8.2	2.8
100	77.0	16.5	5.5
200	154.0	33.0	11.0

If we examine the values given in fig. 1 and 2 and table 1, we may conclude from figure 2 that the goal of pollution control, i.e. preserving the oligotrophic condition of most of our larger lakes, can only be reached if at least 85% of the

phosphorus is eliminated from wastewater as soon as the population density exceeds 50 inhabitants per km<sup>2</sup>. Since high population density usually coincides with intensive agricultural cultivation even 95% phosphorus elimination

from wastewater for a population density of over 100 inhabitants/km<sup>2</sup> will have the desired effect only if the phosphorus losses from agriculture can be reduced concomitantly.

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# Phosphorus Losses from the Soil and the Implications for Water Pollution Control

by René Gächter

Among the macro-nutrients the greatest growth-limiting factors in lakes were found to be phosphorus and sometimes nitrogen. Since both these nutrients, together with potassium, are the main components of inorganic fertilizer, it was assumed that the undesirable eutrophication of our waters was caused not only by municipal and agricultural wastewaters but also by the percolation of minerals and soil erosion from intensively cultivated soil. Topography, soil quality, climate and type of cultivation all have a bearing on nutrient erosion and percolation. To be able to determine at least part of these factors as accurately as possible, we limited ourselves to the analysis of results gleaned in relatively small, easily surveyable drainage areas (1, 2, 3, 4, 9, 10, 11, 12).

Figur 1 shows the nitrogen and phosphorus loads measured in terms of specific surface dimensions in correlation to the portion of the catchment area used for agricultural purposes. A distinction was made only between two very general types of land use, agriculture and forestry, while the method of fertilization and type of cultivation – whether pastureland, meadows or fields – were disregarded. The pre-alpine regions differ from Central Switzerland in their higher altitude, steeper slopes and greater specific run-off. Contrary to Central Switzerland, where cultivation includes natural meadows, pastureland, artificial meadows, viticulture and various types of soil tillage, land use in the pre-alpine regions is more homogeneous (natural meadows and pastureland) (5,8).

In both the pre-alpine regions and Central Switzerland, wooded areas suffer no phosphorus losses worth mentioning. However, as soon as the catchment area is set aside entirely for agriculture, yearly phosphorus losses of about 35 kg P/km<sup>2</sup> and 70 kg/P/km<sup>2</sup> can be expected in the catchment areas of Central Switzerland and the pre-alpine regions respectively. Despite greater specific run-off and less phosphorus fertilization in catchment areas with the 'same' type of soil cultivation, dissolved phosphorus compound concentrations in pre-alpine waters are slightly higher than concentrations found in Central Switzerland. This is due mainly to the fact that in the steeper pre-alpine regions the phosphorus compounds are not only washed away through percolation but also eroded by surface run-off.

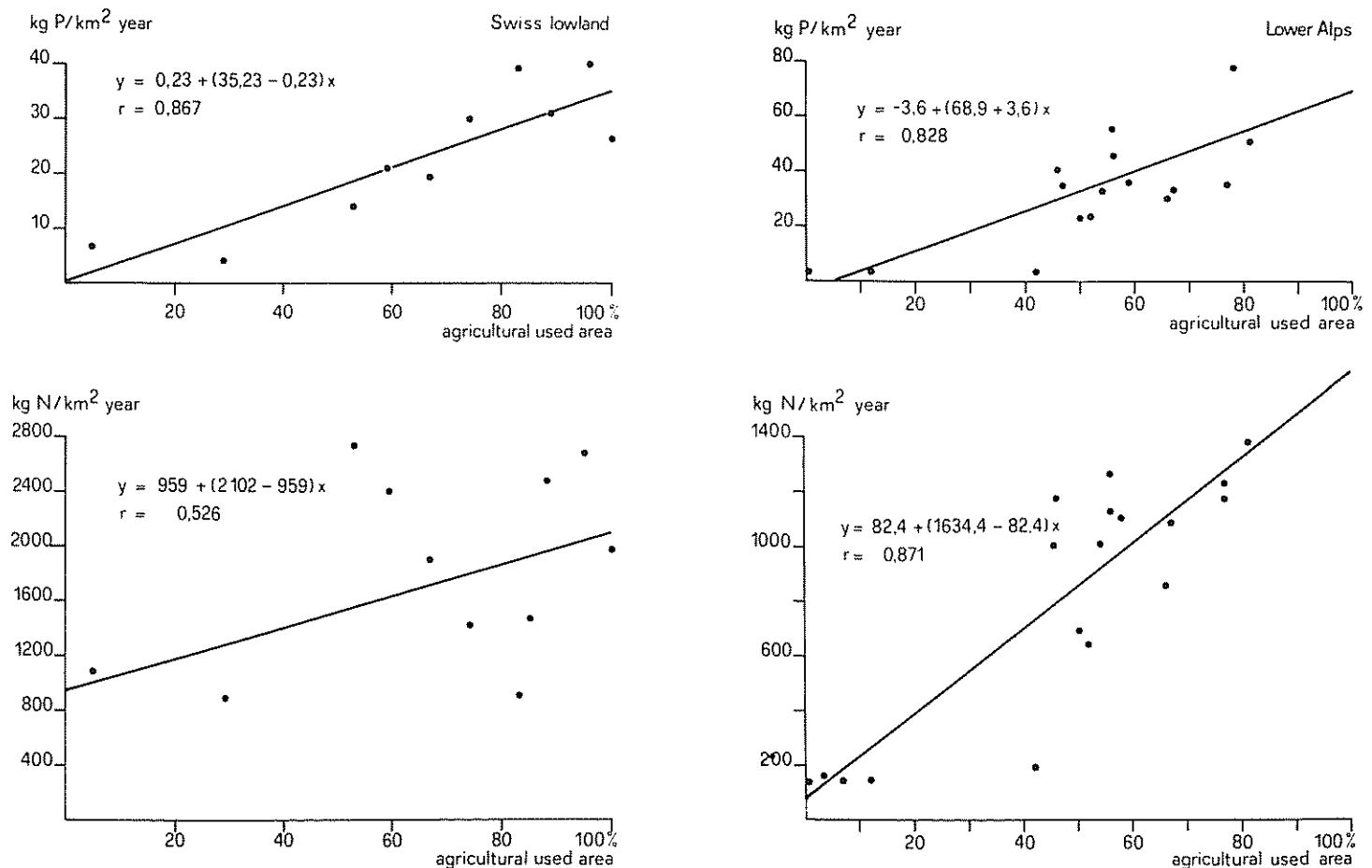


Figure 1

Annual loads of dissolved phosphorus and nitrogen compounds in relation to the relative amount of land of the total

drainage area in the pre-alpine regions and Central Switzerland to be used for agriculture.

In the equation  $y = a + (b + a)x$

'a' stands for the P (N) loads from a specific area used for forestry  
'b' = land used for agriculture  
'x' = 1 signifies that the entire drainage area is used for agriculture.

In the pre-alpine regions nitrogen losses amount to a yearly average of about 82 kg N/km<sup>2</sup> for land used for agriculture alone. In Central Switzerland nitrogen losses are always greater despite the 'same' type of land use, a fact which can be ascribed to increased fertilization as

well as to more intensive biological nitrogen turnover – induced by climatic conditions – in the soil of the lower regions. The heterogeneous pattern of land use in Central Switzerland explains the scattered distribution of the single values around the regression line calcu-

lated for this area. Calculated in relation to the quantity of fertilizer used annually, the nutrient losses from agricultural land lay between 16 to 25 per cent for nitrogen and about 0.7 to 1.4 per cent for phosphorus. Depending on the type of cultivation, the

Figure 1:

The shift in peak potential observed with increasing carbonate concentration permits the determination of the stability of the complexes  $PbCO_3$  and  $Pb(CO_3)_2$ .

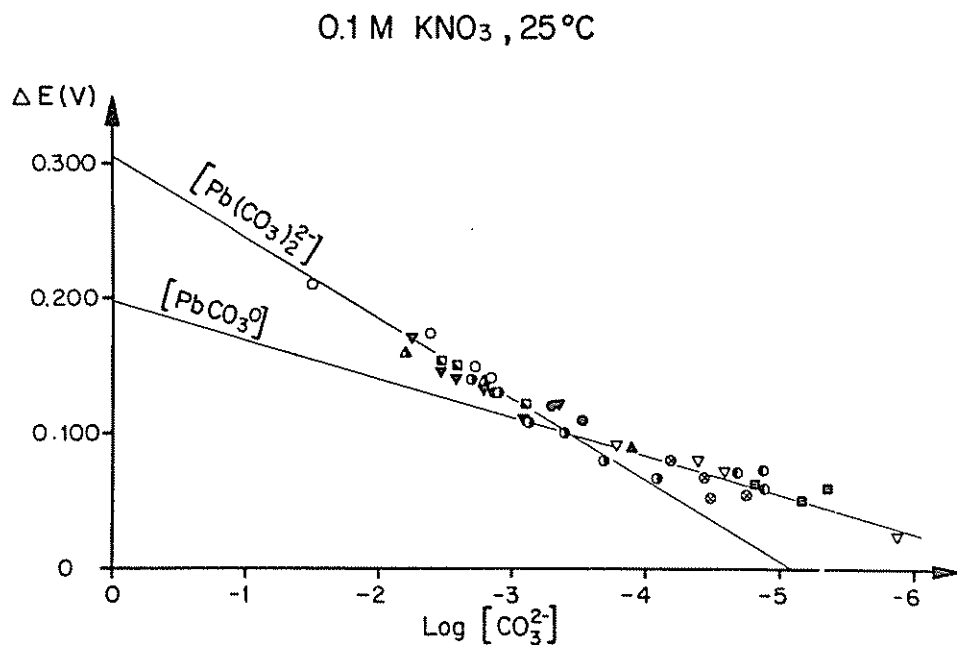


Figure 2:

The speciation of lead(II) in waters containing a total carbonate concentration of  $10^{-3}M$ .

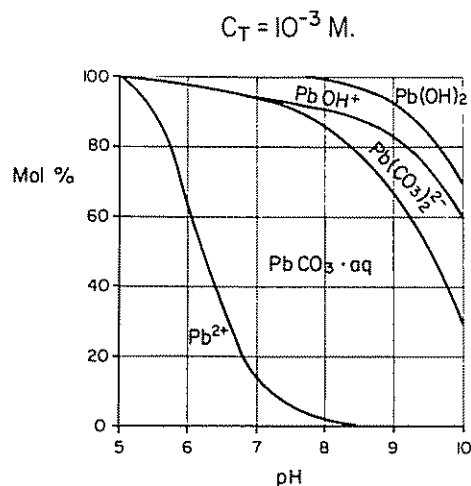
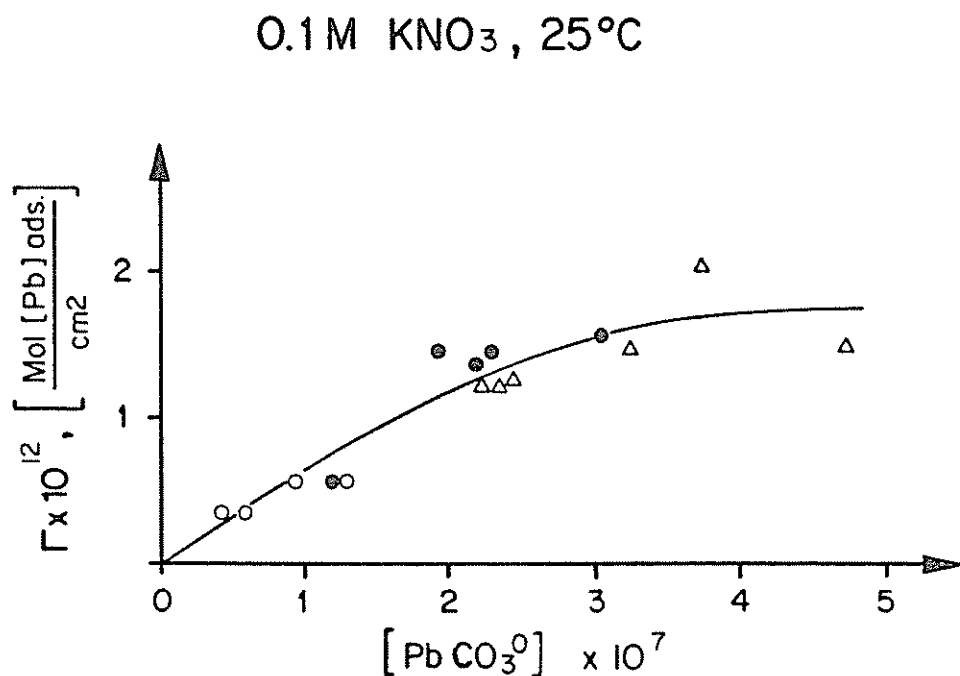


Figure 3:

$PbCO_3$  complexes are adsorbed much more strongly than free  $Pb^{2+}$



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