# Sorption of Zinc on Human Teeth

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Zinc containing dental amalgams are sometimes used as fillings by dentists. The freshly mixed mass of the amalgam alloy and liquid mercury has a plasticity that permits to be conveniently packed or condensed into a prepared tooth cavity. Zinc has been included in amalgams alloys upto 2% as an aid in manufacturing by helping to produce clean and sound castings of the ingots. Although such restorations have a relatively long service life, they are subject to corrosion and galvanic action, thus releasing metallic products into the oral environment. The aim of this paper is to investigate the uptake (sorption) of zinc ionic species on human teeth using the radioactive tracer technique. For this purpose the isotope Zn-65 produced from pile-irradiation of zinc metal was used. The various liquids studied were drinking water (tap water), tea, coffee, red tea and chicken soup. Sorption was studied through immersion of a single human tooth (extracted) in each of these liquids.

## Materials and Methods

### Instrument

As a gamma-ray spectrometer and a gamma counter, a multichannel analyser Model 800 A from Nucleus INC was used. The analyser was connected to a scintillation detector (Bicron) made of a well-type 3x3 inches NaI(Tl) crystal, a photomultiplier tube and a preamplifier. The instrument is also supplied with a Magnacom display monitor

**Radioactive tracer**

The radioactive isotope Zn-65 was prepared by irradiation of ~50 mg zinc metal granules in the Egyptian Research Reactor-1 at Inshas (ERR-1), for 48 hours. Two weeks after irradiation the metal was dissolved in concentrated hydrochloric acid and then made 2 M in hydrochloric acid. The solution was then kept in a dark bottle as a stock solution of zinc in the stable oxidation state Zn(II).

**Uptake experiments**

To study the sorption of zinc species on tooth two equal portions 5-ml each of the investigated liquid (water, drink, etc.), spiked with a suitable amount of the Zn-65 stock solution, were transfered to two similar plastic vials supplied with covers. The amount of the added radioactive tracer was about 20,000 counts/ml/min. A tooth is now transfered to one of the two vials and the activity of one ml from each vial was then measured every half an hour or every hour throughout the first working day and then few times throughout the next working day. Duplicate readings were recorded and the average values were tabulated. After counting, the liquids were returned to the respective vials, which were then tightly closed each with its cover, to prevent evaporation of the liquids. The sorption or uptake percent, U% was evaluated from the starting zinc activity ($A_o$), and the activity at a given time t ($A_t$), using the relation:

$$U(\%) = \frac{A_o - A_t}{A_o} . 100 ,$$

However, the depletion of activity was also followed in the liquid above the tooth compared to the blank experiment in the absence of the tooth, to account for any sorption that might have taken place on the inner walls of the vial.

## Results

**Depletion of Zn activity in presence of a tooth**

In Fig.1 (lower curve) is shown the effect of time on the amount of zinc in drinking water in contact with an extracted tooth as is measured by the activity of the radioactive Zn-65 tracer. The upper curve, representing the results in the absence of a tooth, shows that the uptake of the zinc species on the walls of the used plastic vial is negligible. In presence of a tooth, on the other hand the activity is seen to decrease remarkably with the elapse of time. This picture indicates that teeth serve as a natural sieve holding the zinc species, which might be subsequently eliminated in the course of cleaning the mouth by a toothpaste and brush. Fig.2 shows the percent uptake of zinc from water on the tooth at the various intervals of time. After $2^1/_2$ hours the sorption of zinc on the tooth is seen to be more than 50% of the starting amount.

Next to water tea and coffee are perhaps the most frequent liquids, the man drinks. The results on the depletion of zinc radioactivity due to the presence of a tooth are demonstrated in Figs 3 and 4 for tea with and without sugar, respectively. In general, the depletion of the zinc content, which is parallel to the radioactivity measured, is seen to be lower than in case of water. Moreover, the presence of sugar in this medium has almost no effect on the process. This is also clear from the plot of the percent uptake of zinc versus the time of immersion (Fig.5). The activity-time data for soluble coffee (Nescafee) with and without sugar, shown in Figs. 6 and 7, respectively, indicate somewhat less sorption, compared to water and tea. The percent uptake, however, clearly decreases when sugar is added to the soluble coffee (Fig.8). On the other hand, the results on the effect of time on the zinc activity in soluble coffee with milk are shown in Figs. 9 and 10, for this drink with and without sugar, respectively. The presence of milk changes the activity-time picture not only for the experiment with the tooth, but also for the blank experiment in absence of the tooth, perhaps due to the hydrolysis and complex formation of the zinc species in presence of milk.

In Figs.11 and 12 are shown the activity-time relationships for red tea, with and without sugar, respectively. Lower sorption of zinc is exhibited in this drink, compared to normal tea, and is further lower in presence of sugar (Fig.13).

Finally the data for the effect of chicken soup on zinc sorption on the tooth with the elapse of time are demonstrated in Figs.14 (activity-time plot) and 15 (% uptake-time plot). It is clear that sorption here is considerably less than from pure water, and is also less than from tea with or without sugar.

**Desorption of Zinc from the Tooth**

In this section are given the results on the counting of teeth used in the sorption experiments before and after vigorous rinsing with tap water for about 3 minutes (Table 1)

**Table 1. Counting rate of teeth used in the sorption experiments with radiozinc before and after through washing with tap water.** (Counts/min)

| Liquid used in the experiment | Activity before washing | Activity after washing |
|---|---|---|
| tap water | 96435 | 90523 |
| tea with sugar | 46222 | 42175 |
| tea with sugar (porcelain) | 704 | 165 |
| tea without sugar | 53789 | 48702 |
| coffee with sugar | 22572 | 20307 |
| coffee without sugar | 33254 | 30784 |
| coffee with sugar and milk | 18455 | 17417 |
| red tea with sugar | 11740 | 8152 |
| red tea without sugar | 21943 | 19118 |
| chicken stock soup | 704 | 165 |

## Discussion

The difficult desorption of zinc from teeth might indicate that its uptake by the tooth is largly due to absorption by the tooth material, mainly made of hydroxyapatite [(1)]. The dentin matrix surrounds dentinal tubules that have been filled with odontoblastic processes that secreted the dentin matrix. Moreover some odontoblastic processes are known to extend through the dentin tubules to the dentoenamel junction (DEJ). The dentin permeability which has been adequately studied during the last two decades would promote the diffusion of ions through the enamel and dentin matrices [(2)]. The dentin tubules, no matter has small the diameter, establish a diffusion gradient through which ions and molecules can move, even against possitive hydraulic pressure. Thus it has been reported that zinc ions are adsorbed to a great extent by dentin [(2)]. The capillary beds and vascular dynamics are probably capable of removing relatively large amounts of various chemicals. On the other hand porcelain does not hold any significant amount of radiozinc as is clear from the data in the table for an experiment in which tea with sugar has been used in the sorption study.

In case of zinc-containing dental amalgams the corrosion of the amalgam gives rise to the ions of mercury, silver, tin, copper and zinc. The corrosion of such amalgams has been studied using neutron activation and gamma ray spectrometry [3-5]. In Fig.16 is given the gamma-ray spectra of the corrosion products of a zinc containing dental amalgam in some liquids taken by man. The ions released from the amalgam are subsequently sorbed on the teeth and this study demonstrated the behaviour of the zinc ions using the radioactive tracer technique with Zn-65 ($t_{1/2}$= 243.8d) as a radiotracer of zinc. The data in Table 1 show that the sorption of zinc by natural teeth decreases in the order: water > tea > coffee > chicken soup > red tea.

The diffusion of some zinc ions through the teeth is not thought to be harmful to the human body. On the contrary, zinc among heavy metals is probably the second essential after iron. Thus many Zn-containing proteins have been identified and most of them are enzymes such as carbonic anhydrase, which catalyses the hydration and dehydration of carbon dioxide. On the other hand, the study on zinc throws some light on the behaviour of mecrcury, since the two elements belong to the same group (2B) in the periodic table and both of them have two s electrons outside a filled shell. Mercury, however, is a toxic element and care for its toxisity has been frequently undertaken by chemists and dentists since it is also produced in the course of corrosion of dental amalgams as is clear from Fig.16 [3-5]. Most released mercury is from the $\gamma_2$ phase [2]. Due to the importance of mercury behaviour the investigation of its sorption by teeth using the radioactive tracer technique with Hg-203 ($t_{1/2}$ = 46.6 d) is now under way.

## References

1- Dental Materials, Properties and Manipulation, Robert G.Craig, William J. O'Brien and John M.Powers, Sixth Eddition, Mosby-Year Book, Inc. 1995.

2- Restorative Dental Materials, Edited by Robert G. Craig, Ninth Edition, Mosby Year Book, Inc. 1993.

3- A.Alian, Elsayed Hassnein, A.Kamar, M.El-Sharkawi. Investigation of Corrosion of Alloys Using Neutron Activation and Gamma-Ray Spectrometry. Part I. Principle of the Method and its testing on Dental Amalgams Egyptian Dent. J. 21: 1, (1975).

4- Elsayed Hassanein, A.Alian, R.Shabana, M.Taher. Investigation of Corrosion of Alloys Using Neutron Activation and Gamma-Ray Spectrometry. Part II. Effect of Certain Oral Environments on the Corrosion of Dental Amalgam, Egyptian Dent. J., 21, 2, 1-12 (1975).

5- M.Nagi, A.Alian. A study on Galvanic Degradation of Dental Amalgam Using Activation Analysis Assessments, J. Radioanal. Chem., Vol. 60, No.1, 65-71 (1980).

# Figure Captions

Fig.1. Effect of time on radiozinc activity in tap water in presence of a human tooth.

FIg.2. Percent uptake of radiozinc from water on the tooth as a function of time.

Fig.3. Effect of time on radiozinc activity in tea with sugar in presence of a human tooth.

Fig.4. Effect of time on radiozinc activity in tea without sugar in presence of a human tooth.

FIg.5. Percent uptake of radiozinc from tea on the tooth as a function of time.

Fig.6. Effect of time on radiozinc activity in soluble coffee with sugar in presence of a human tooth.

Fig.7. Effect of time on radiozinc activity in soluble coffee without sugar in presence of a human tooth.

FIg.8. Percent uptake of radiozinc from coffee on the tooth as a function of time.

Fig.9. Effect of time on radiozinc activity in soluble coffee with milk and sugar in presence of a human tooth.

Fig.10. Effect of time on radiozinc activity in soluble coffee with milk in presence of a human tooth.

Fig.11. Effect of time on radiozinc activity in red tea with sugar in presence of a human tooth.

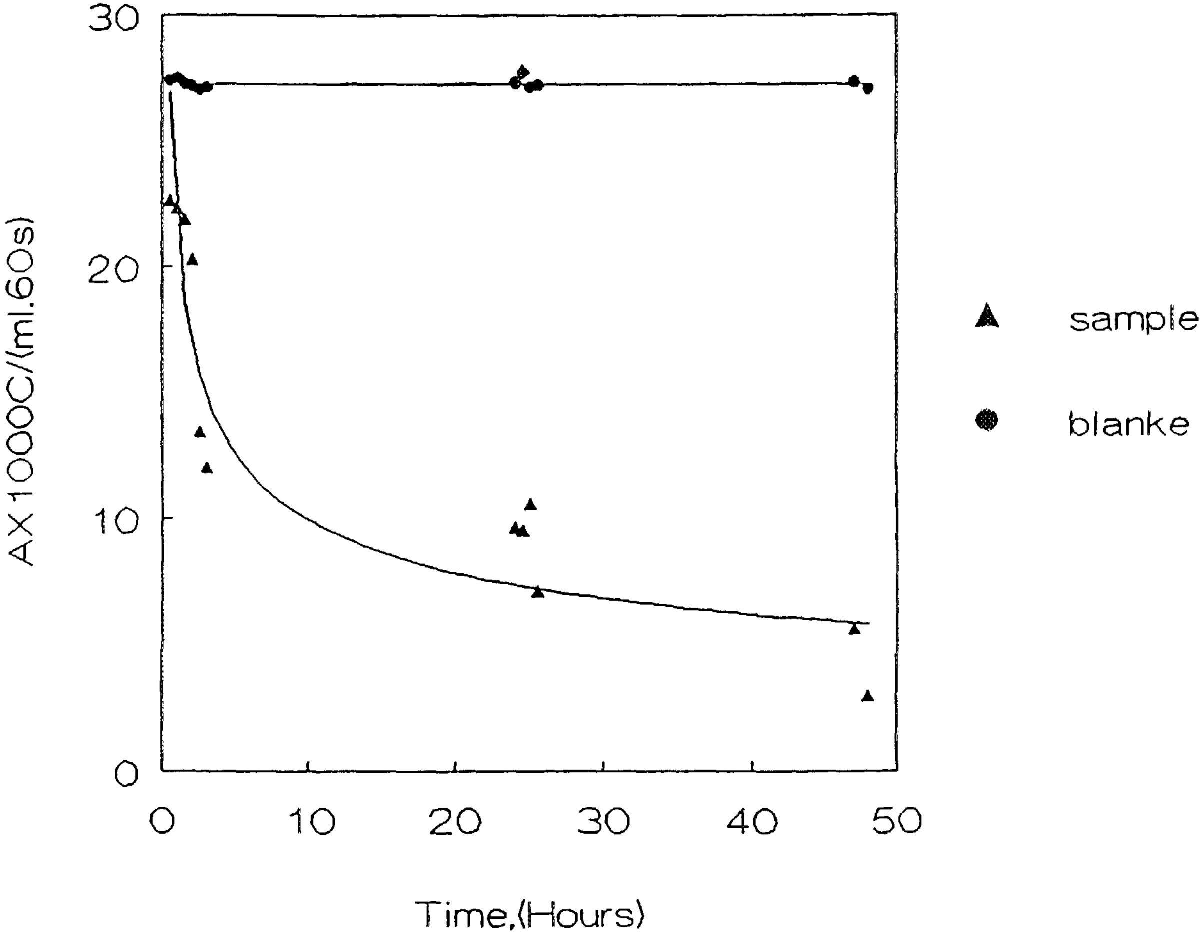
Fig.12. Effect of time on radiozinc activity in red tea without sugar in presence of a human tooth.

FIg.13. Percent uptake of radiozinc from red tea on the tooth as a function of time.

Fig.14. Effect of time on radiozinc activity in chicken soup in presence of a human tooth.

FIg.15. Percent uptake of radiozinc from chicken soup on the tooth as a function of time.

Fig.16. The gamma-ray spectra of the corrosion products of a zince-containing dental amalgam in some liquids taken by man.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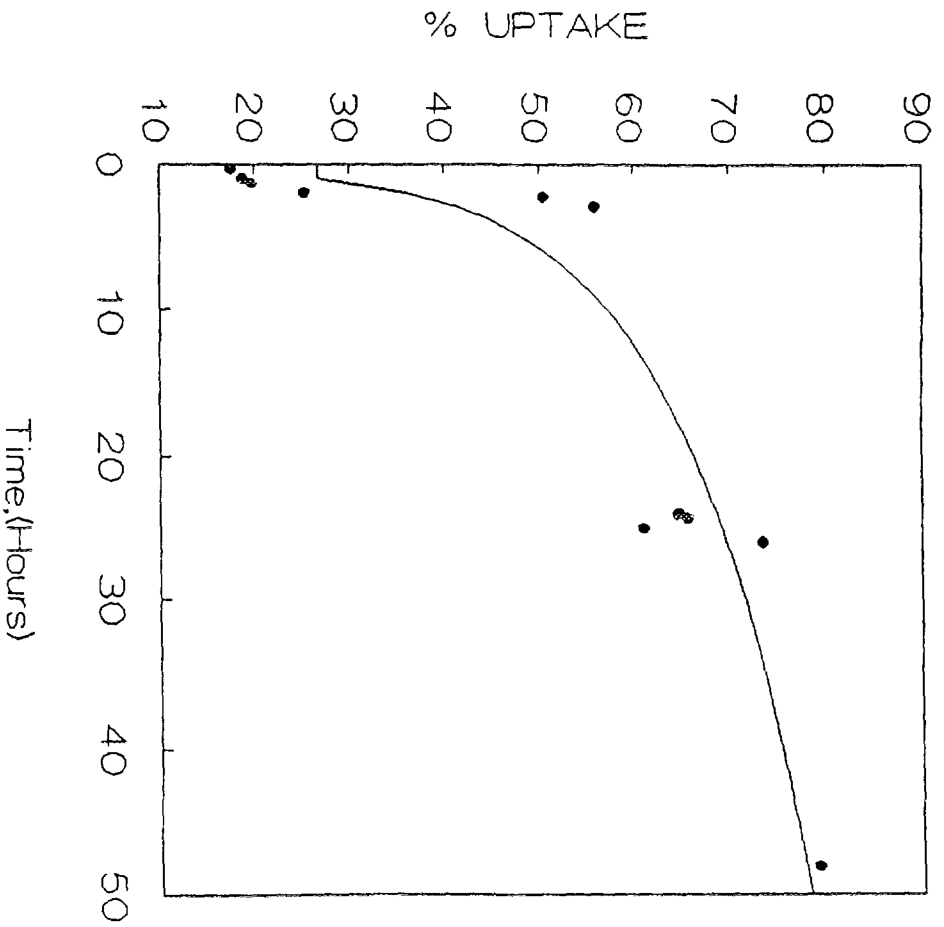
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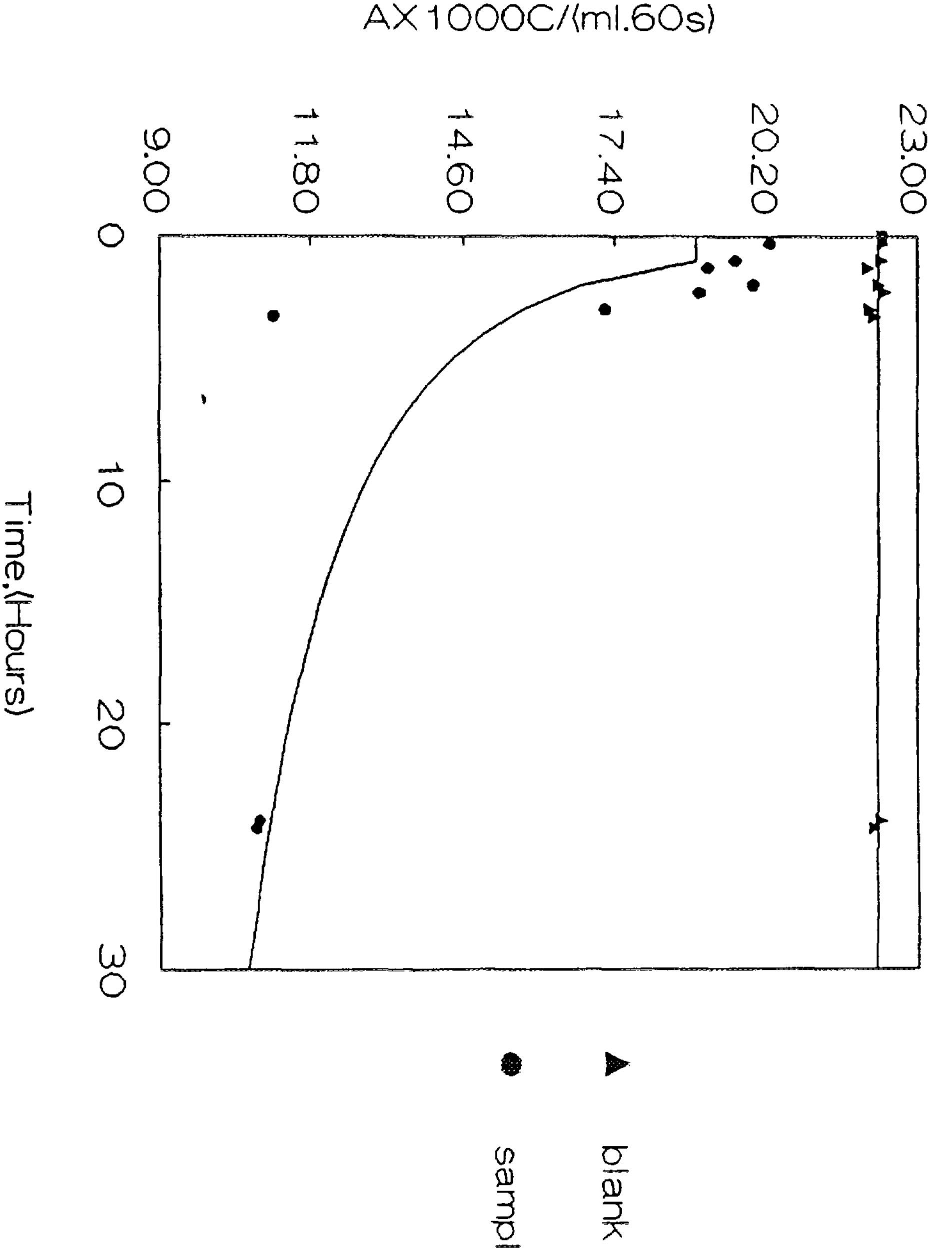

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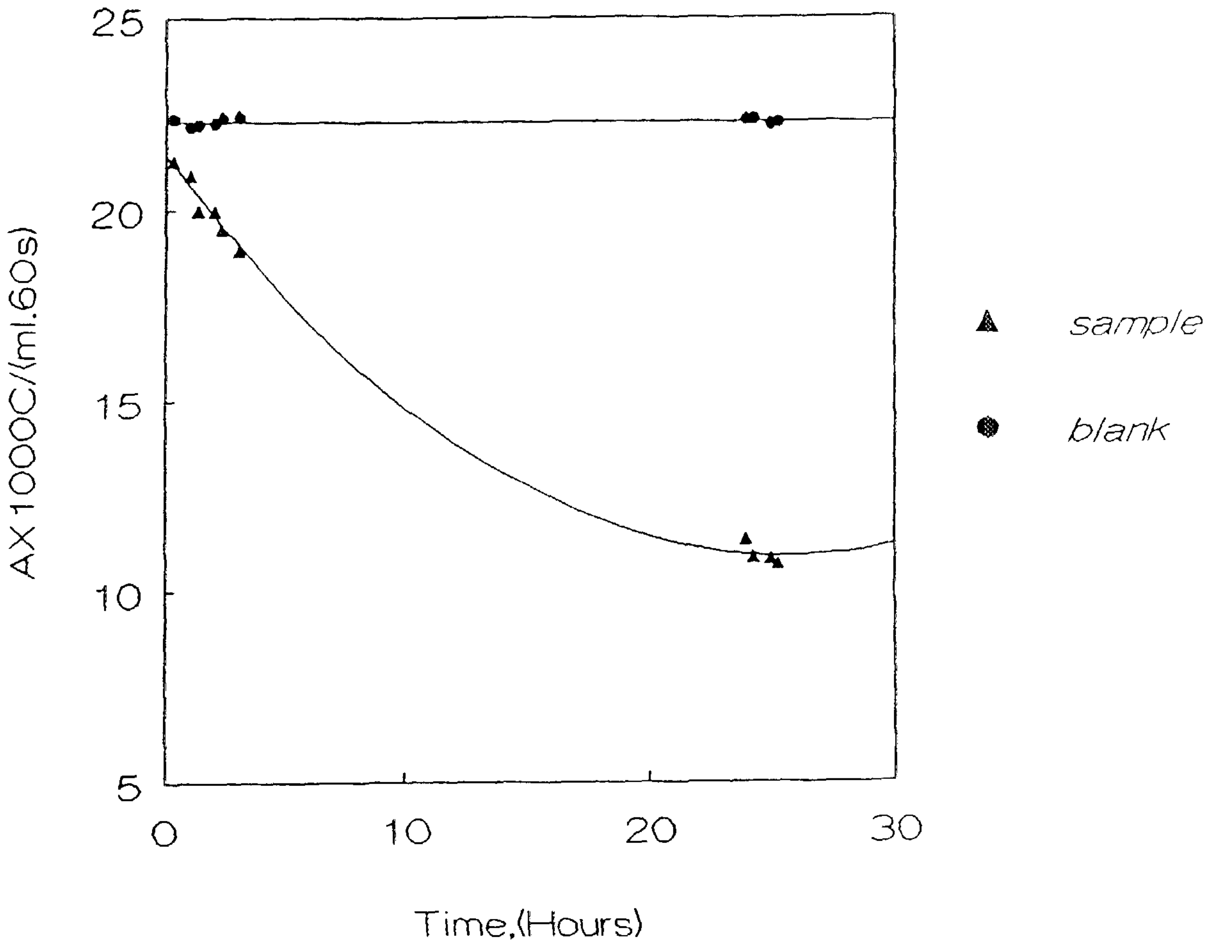
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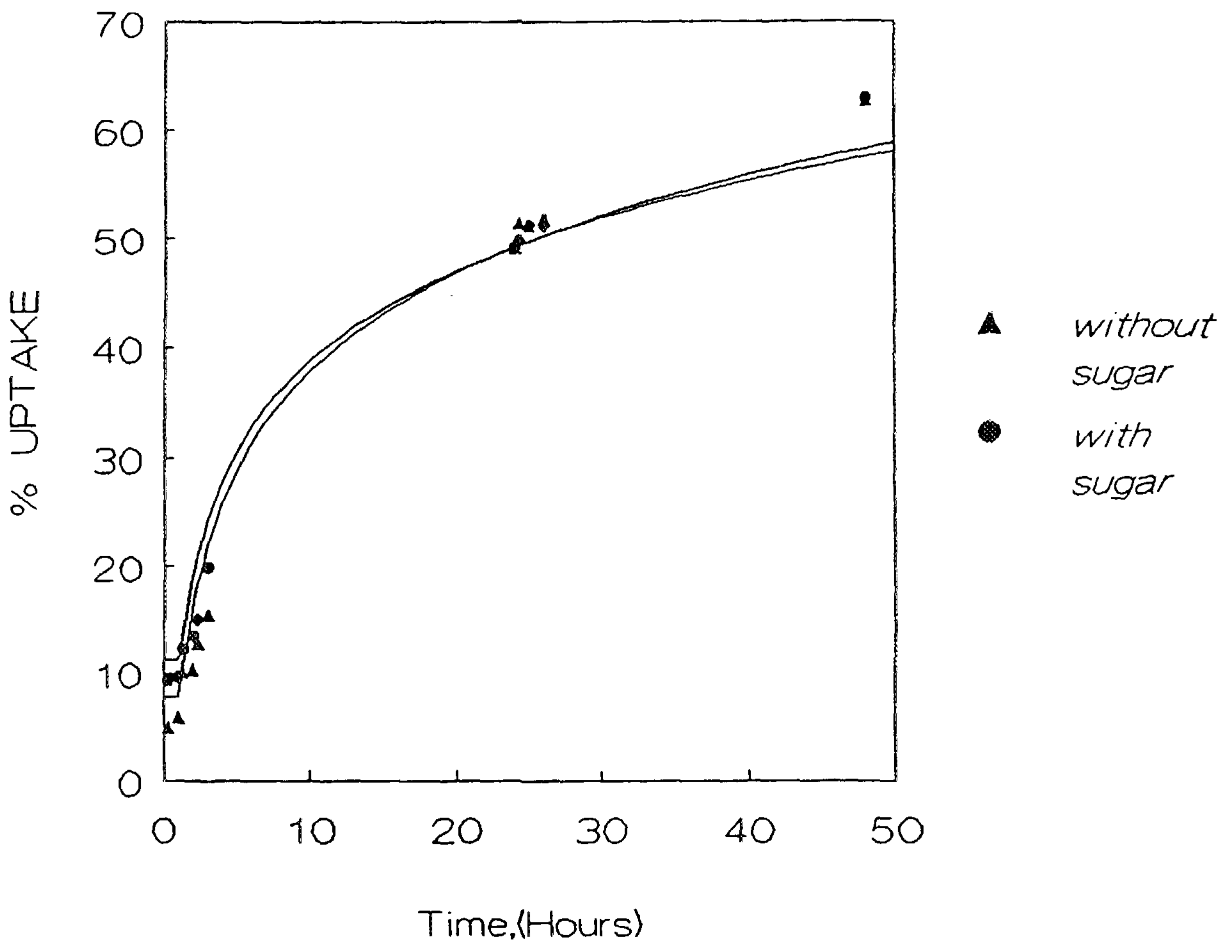
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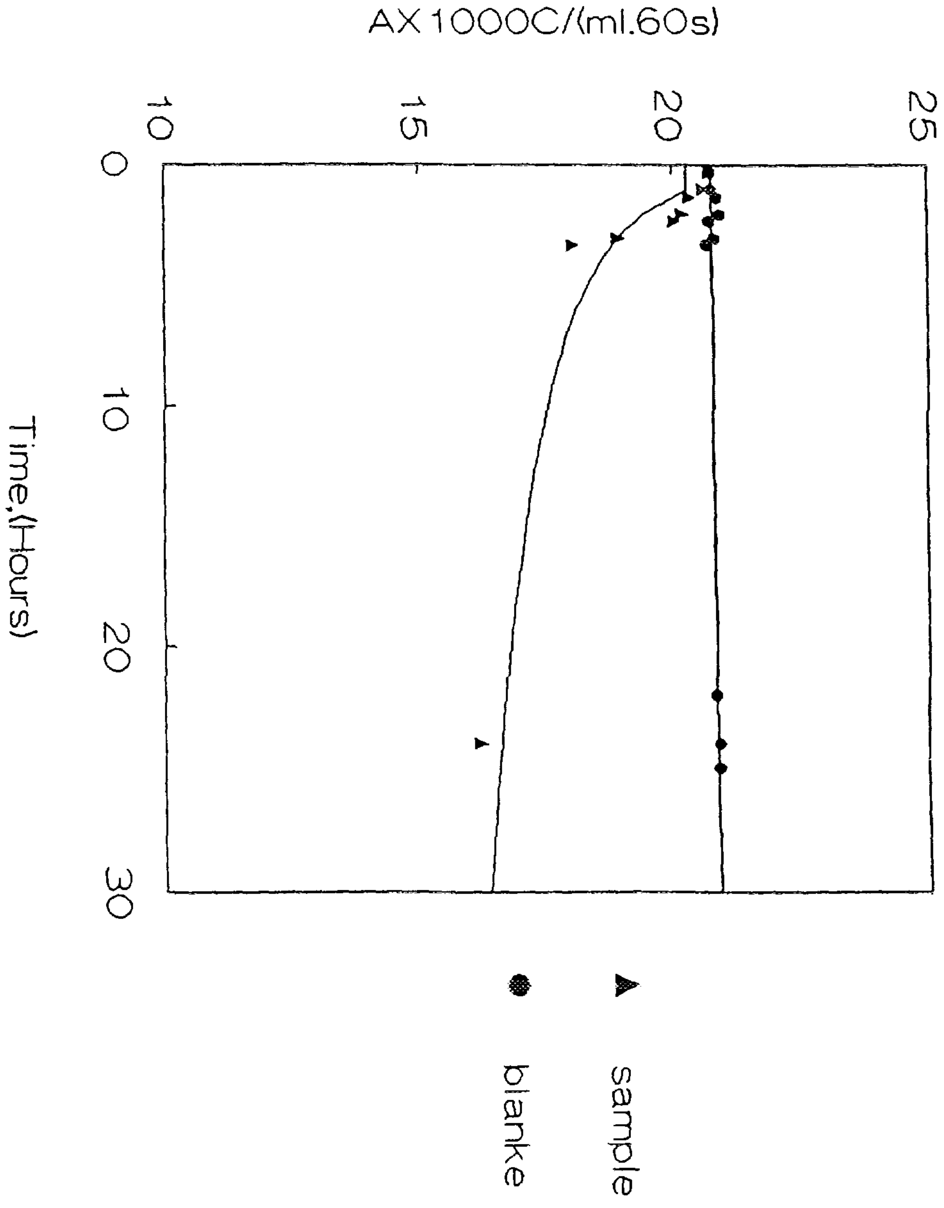
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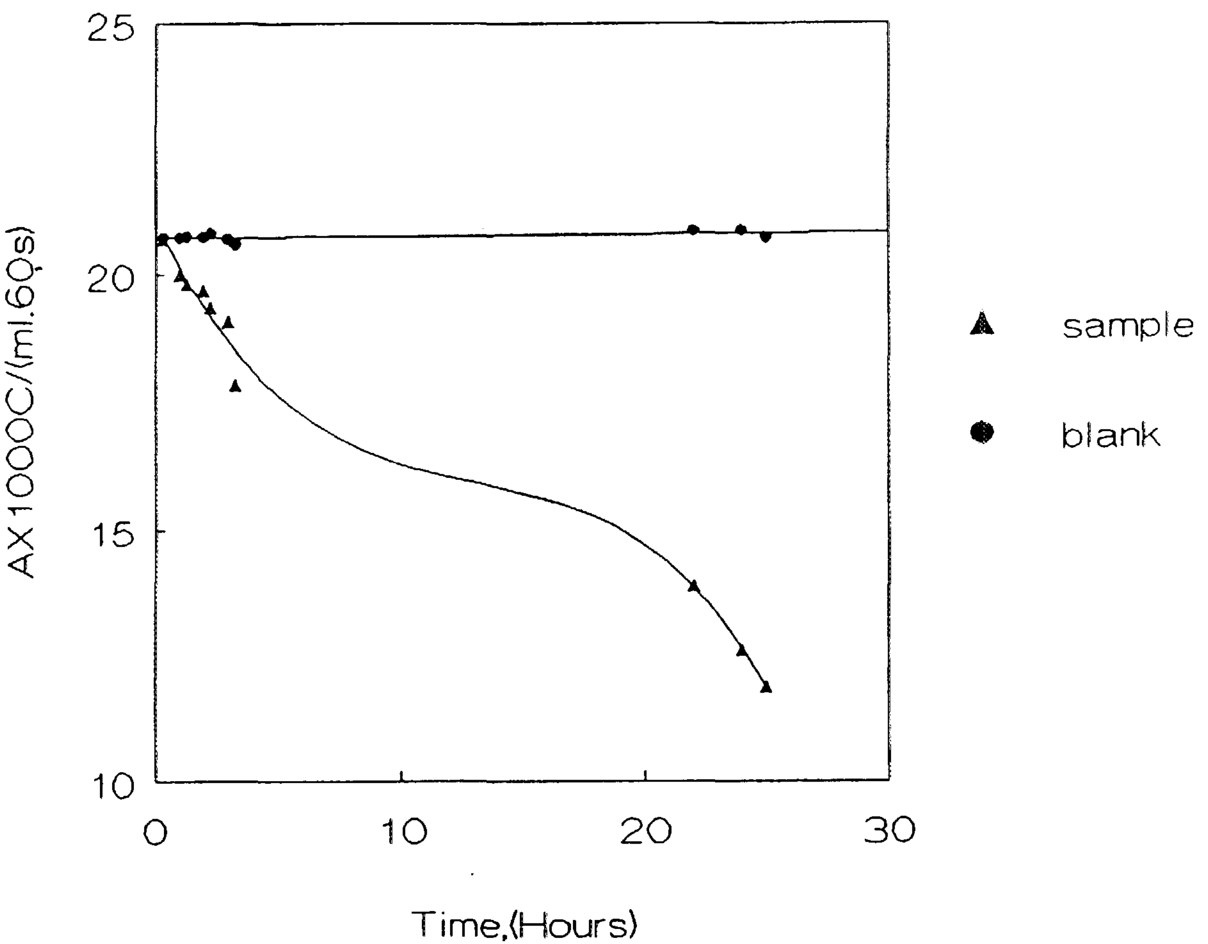
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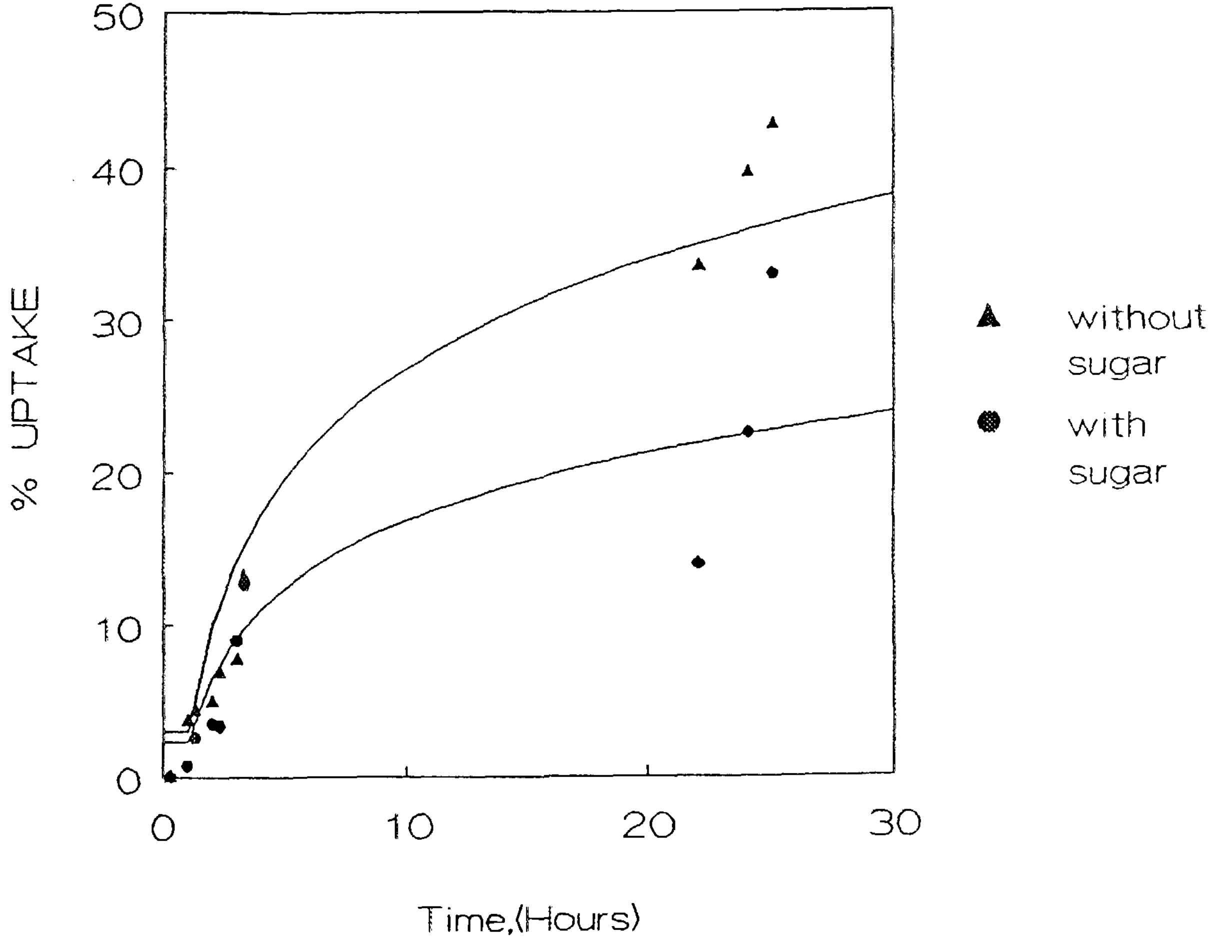
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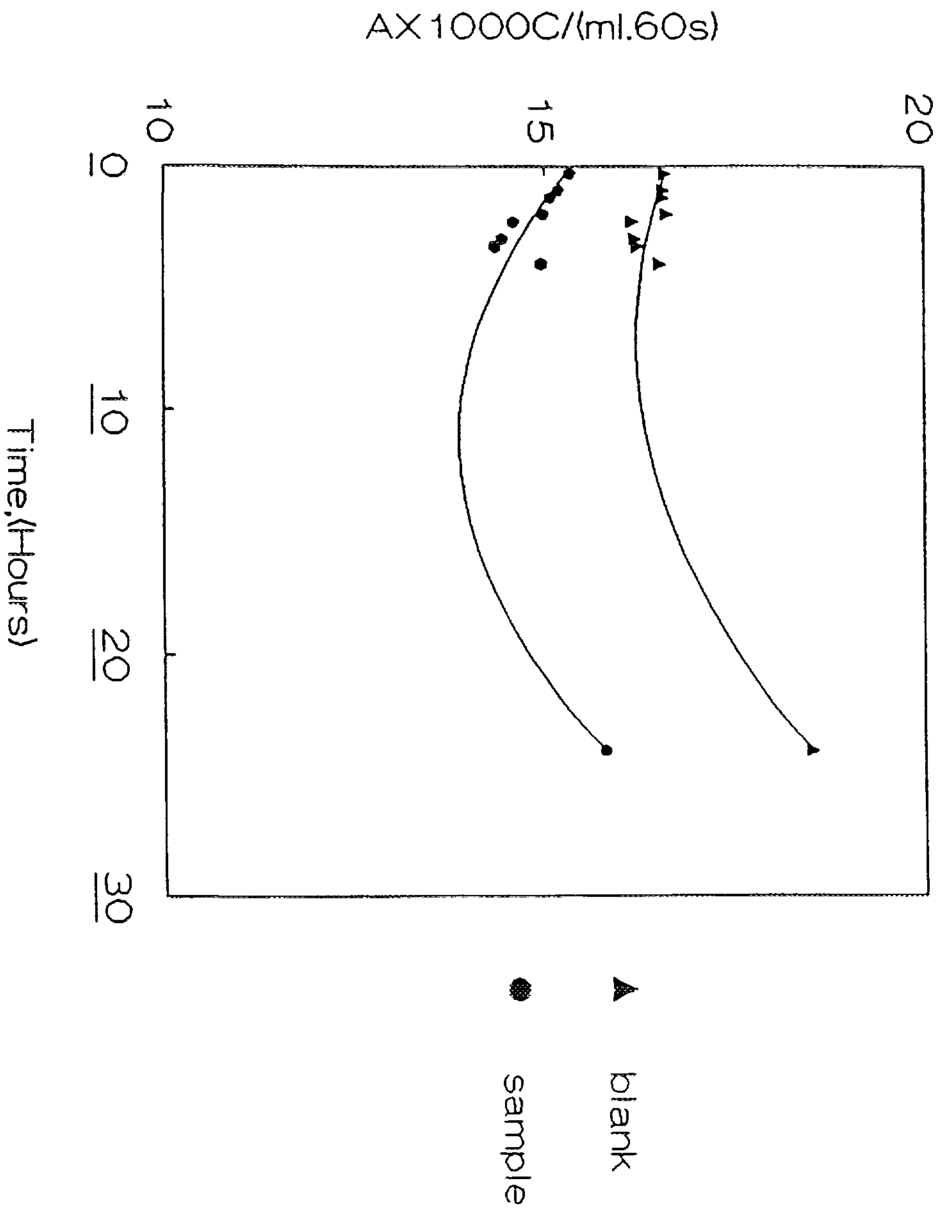
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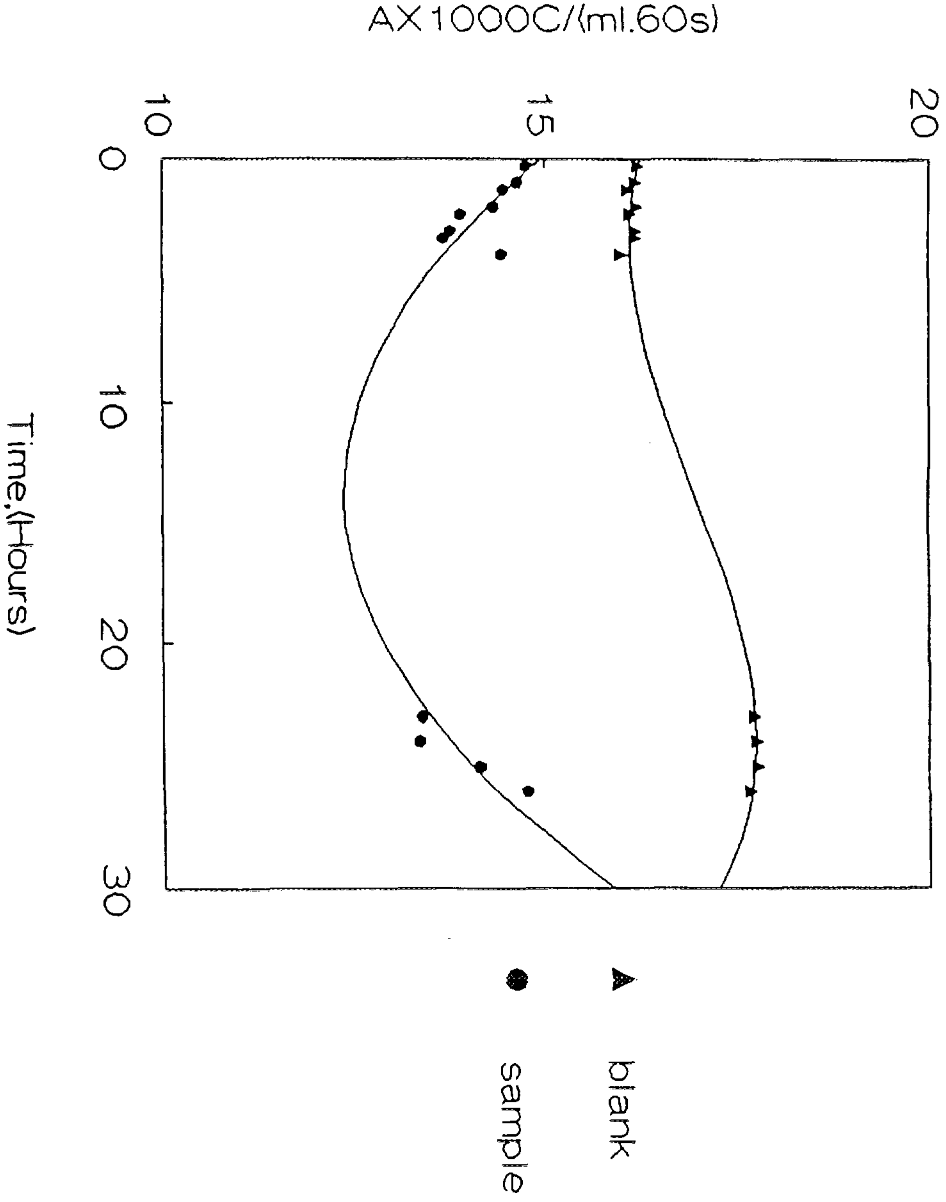
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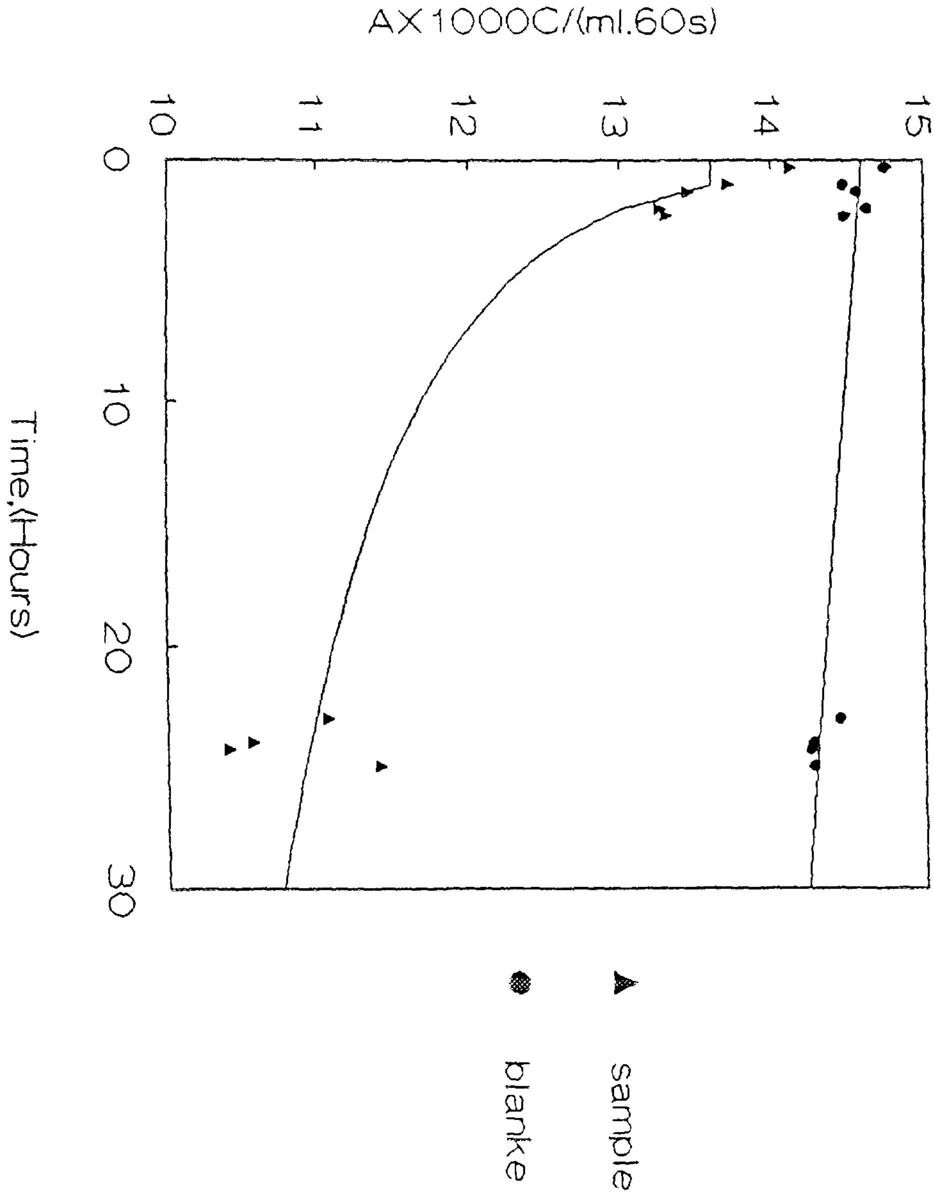
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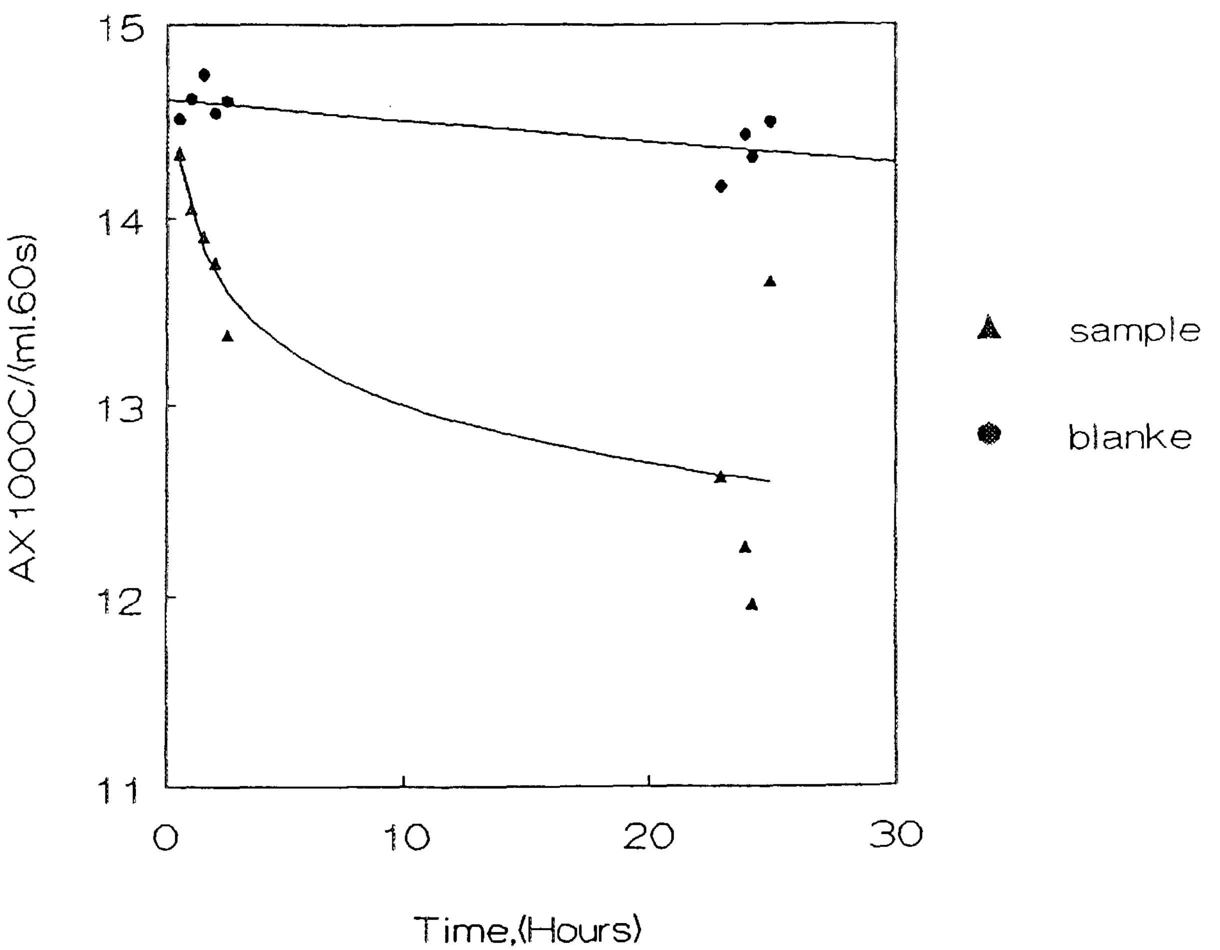
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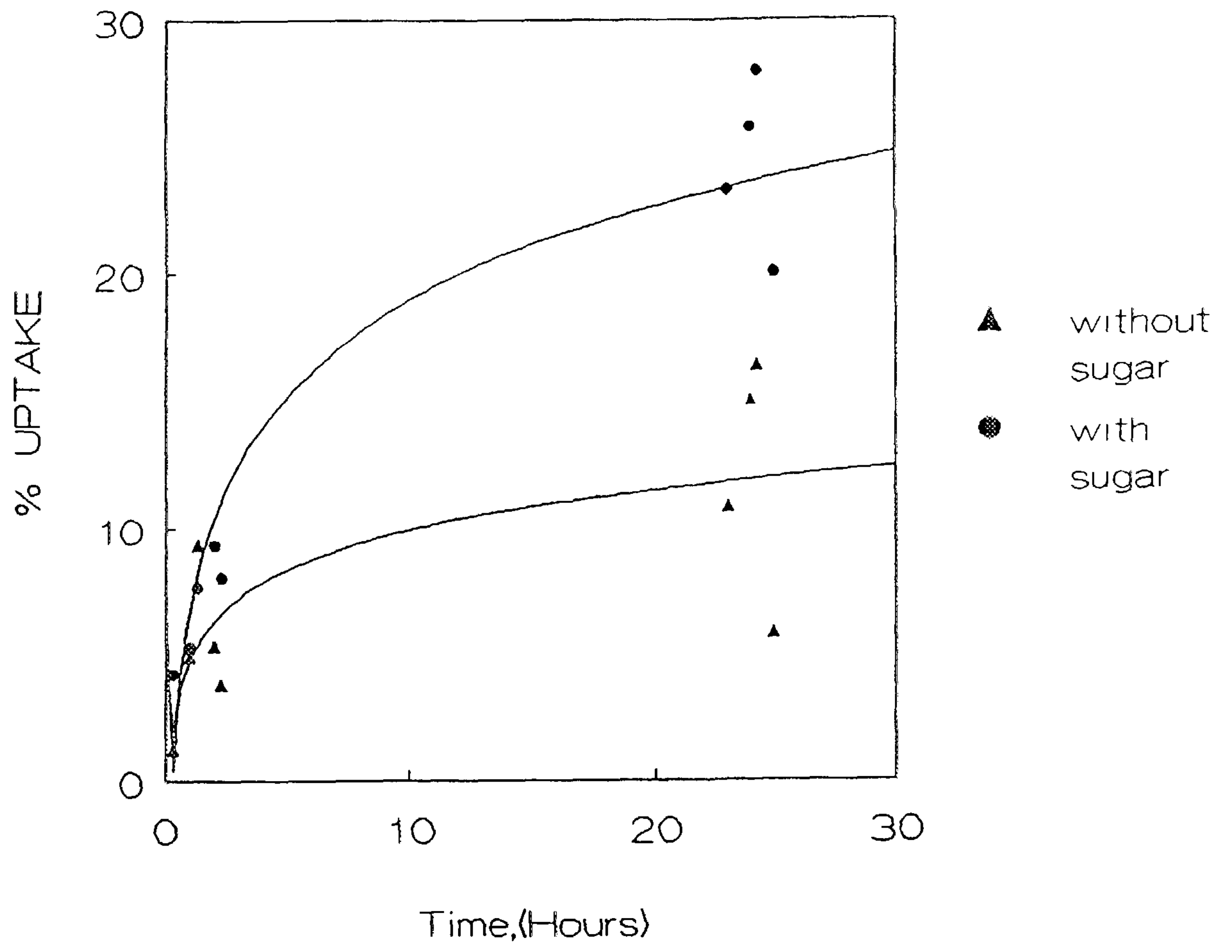
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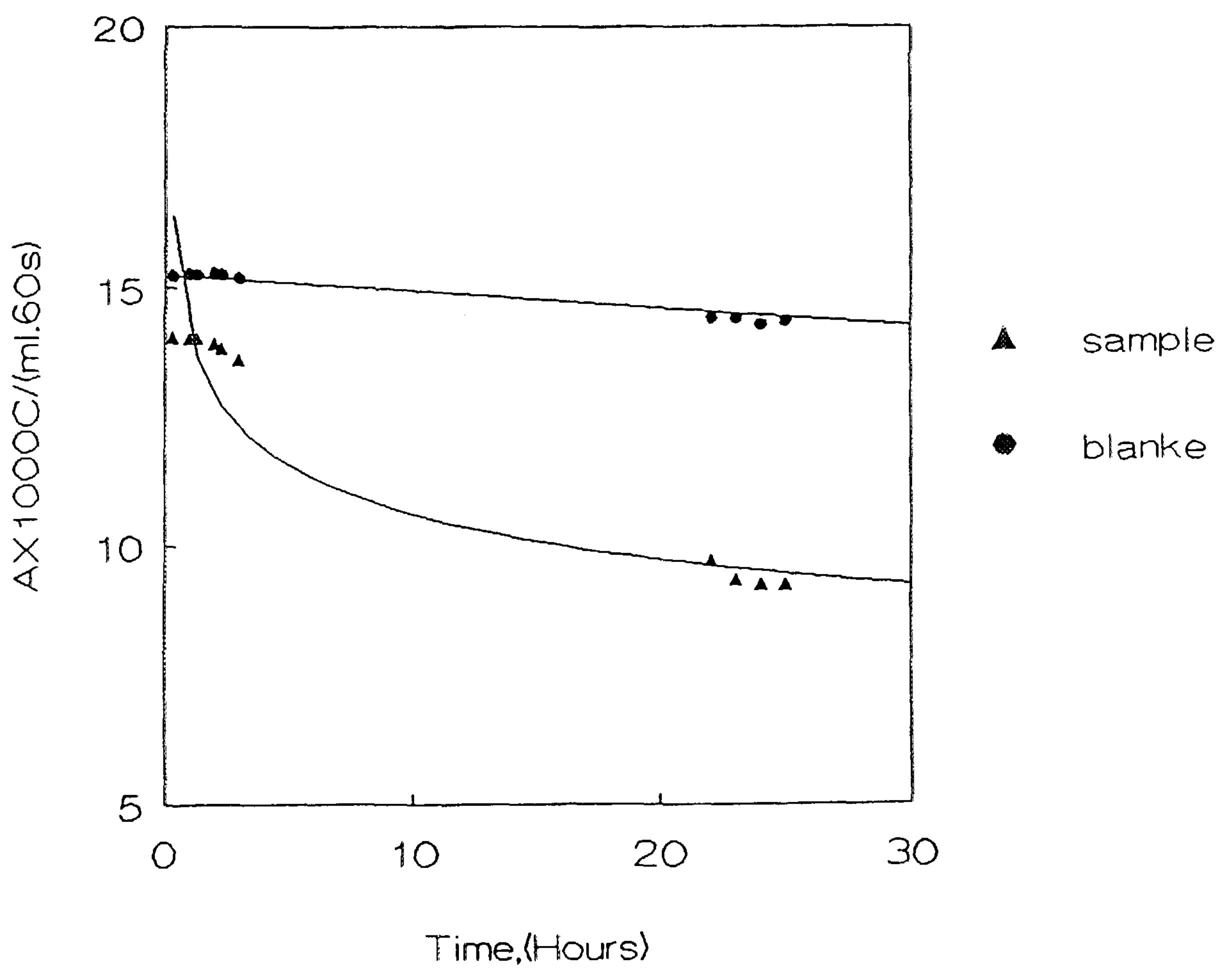
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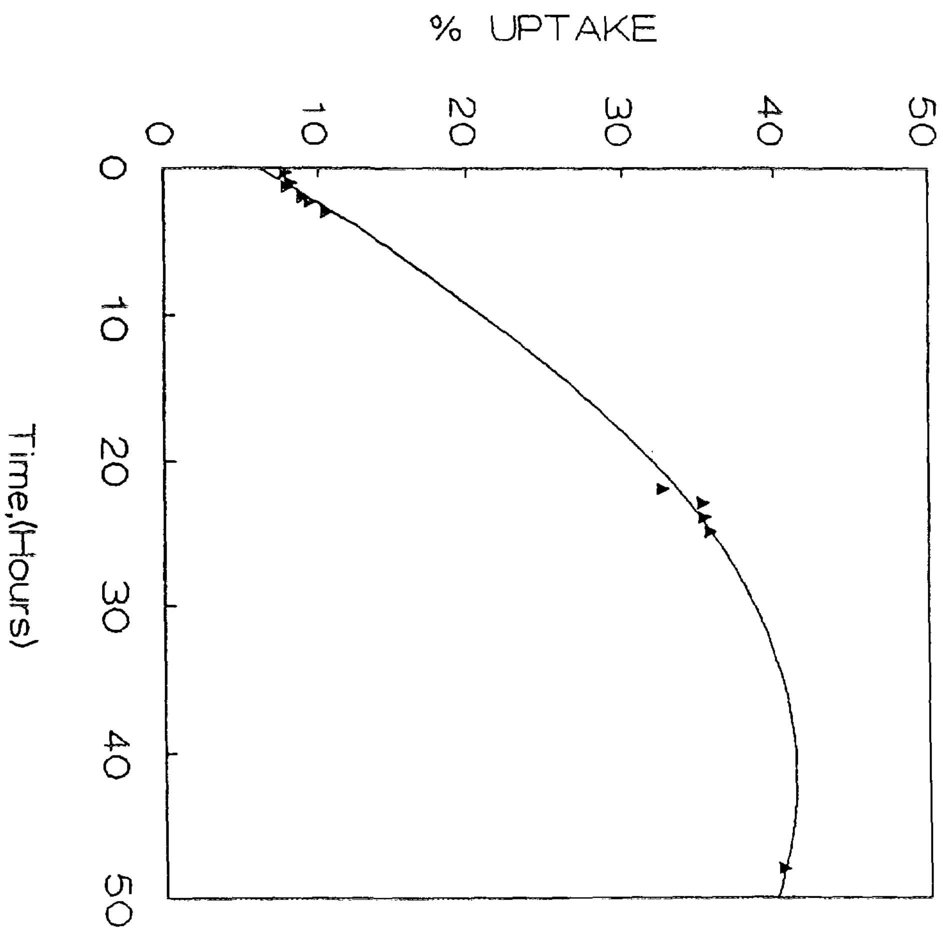
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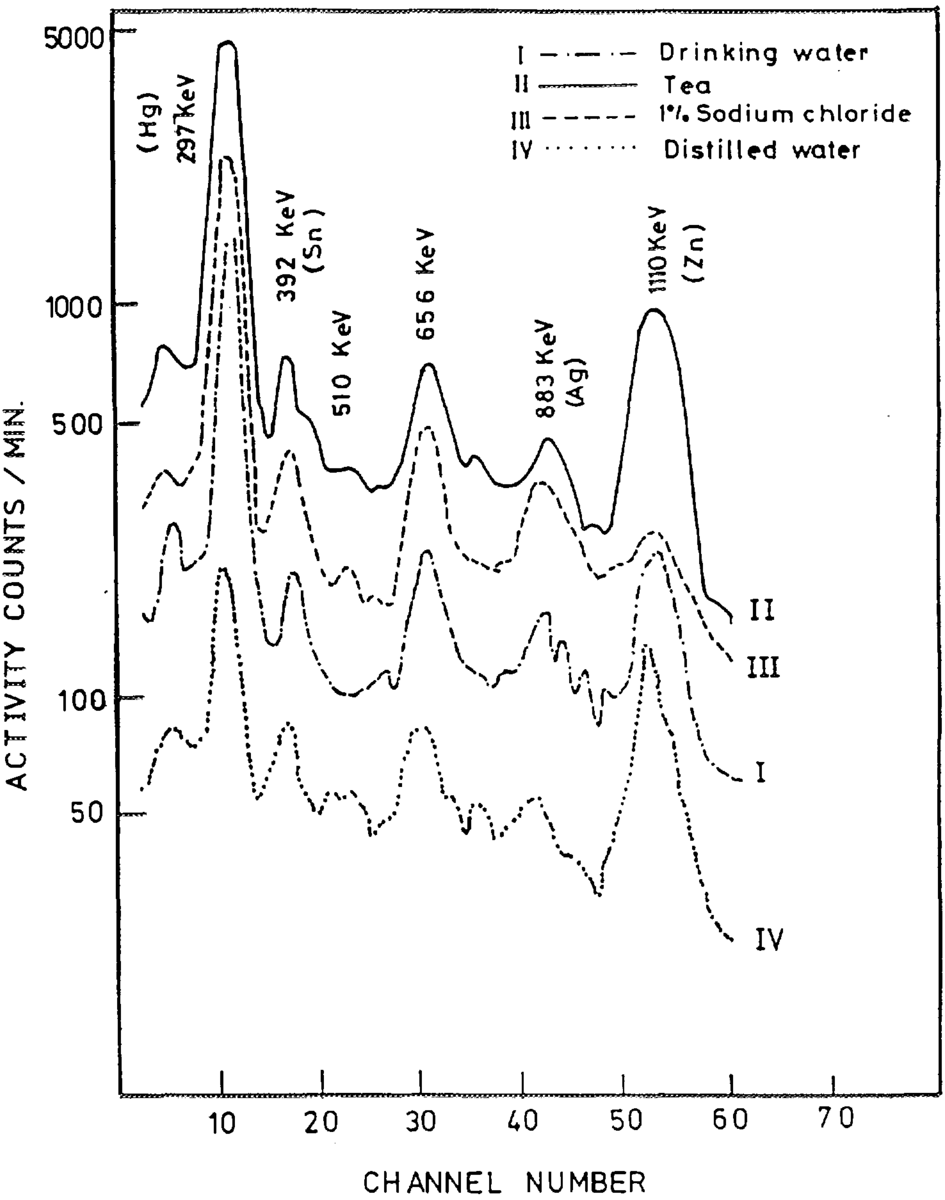

I Drinking water
II Tea
III 1% Sodium chloride
IV Distilled water
(Hg) 297 KeV
392 KeV (Sn)
510 KeV
656 KeV
883 KeV (Ag)
1110 KeV (Zn)
5000
1000
500
100
50
ACTIVITY COUNTS / MIN.
10
20
30
40
50
60
70
CHANNEL NUMBER
II
III
I
IV