Screening of Various Adsorbents for Protection against Paraquat Poisoning

by

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The herbicide paraquat has been used extensively in the United States for weed control for several years. It is available to farmers primarily as paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride) 29.1% liquid concentrate containing 2 lbs paraquat cation per gallon. However, 42% liquid concentrate paraquat bis(methylsulfate)-(1,1'-dimethyl-4,4'-bipyridinium bis(methylsulfate) has been used to some extent. Since paraquat was first introduced into agricultural practice a few ill-effects in applicators have occurred in this country, mostly due to local irritant effects of the caustic material on the skin or in the eyes. One reported nonfatal case of ingestion presented signs of superficial ulceration of the oropharynx (PASI and HINE 1971). In the United Kingdom where the herbicide has been used for a much longer period of time, a number of serious poisonings and deaths have been reported as a result of having accidentally or intentionally ingested relatively small amounts of the liquid concentrate formulation (BULLIVANT 1966; CAMPBELL 1969; CARSON 1969; CLARK et al. 1966; DUFFY 1968; FENNELLY et al. 1968; KERR et al. 1968; MATTHEW et al. 1968; MOURIN 1967; OREOPOLULES et al. 1968). The deaths occurred primarily as a result of irreversible pathological changes in the lungs.

The main therapeutic efforts in ingestion cases are directed at reducing absorption of toxin from the GI tract via lavage, cathartics and adsorbents. Much of the research on the removal, by adsorption, of accidentally ingested drugs and poisons has involved the use of activated charcoal (ANDERSON 1948; CHIN et al. 1969; DECKER et al. 1968, 1968a, 1969). Some recent work, however, has pointed to the value of investigating substances other than charcoal for removal of accidentally ingested toxins such as paraquat (BROWNE 1971; CLARK 1971). The purpose of the present study was to screen various materials to assess their potential as adsorbents for ingested paraquat in an effort to determine the most suitable materials for further study on experimental animals or human beings. Since the completion of this study, CLARK (1971) reported Bentonite and Fuller's Earth to be effective adsorbents in vivo as well as in vitro. Results of the present study are submitted for any who may wish to further explore adsorption of paraquat by various materials.

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EXPERIMENTAL

Screening of adsorbents was carried out in three phases. The first phase involved initial screening of 25 different materials to determine which were most suitable for further study. The procedure used was as follows: One-half ml of paraquat liquid concentrate (29.1% paraquat cation) was added to 20 ml of simulated gastric juice made up according to the formula of GUDIKSEN (1943). This was followed by the addition of 10 ml of an aqueous slurry containing 5 gm of adsorbent. The flask was then shaken for 20 minutes using a Burrell wrist action shaker while being maintained at a temperature of 37°C in a constant temperature bath. After shaking, the solution was separated from the solid contents of the flask either by filtration through Whatman No. 42 filter paper or by centrifugation. One ml of this clear solution was diluted to 100 ml with water. Finally, 2 ml of 0.2% sodium dithionite in 0.2 N NaOH solution was added to 10 ml of this dilution. The developed color was read immediately at 395 mμ in a spectrophotometer. Optical density readings were converted to percent paraquat removed from the simulated gastric solution.

Information obtained from initial screening in the first phase was used to determine the adsorptive materials to be tried in the second phase. In order to simulate experimental conditions which might result during accidental ingestion of paraquat into the stomach and supportive first-aid treatment, the procedure described by DECKER et al. (1968) regarding removal of various drugs by activated charcoal was followed. In this procedure 100 ml of artificial gastric juice was placed in a 250 ml Erlenmeyer flask incubated at 37°C. Two ml of the paraquat concentrate (29.1% paraquat dichloride) were added directly to the flask and the contents shaken for 1 minute with a Burrell Wrist action shaker. A slurry of 5 gm of the adsorbent in 50 ml of water was then quantitatively transferred to the flask and incubation with shaking was continued. After 20 minutes (a simulated elapsed time from accidental ingestion until definitive treatment such as gastric lavage accompanied by supportive therapy could be administered) the adsorbent was separated from the contents of the flask either by filtration through Whatman No. 42 filter paper or by centrifugation. Analysis of the resultant solution was accomplished by first taking 1 ml of the filtrate and diluting to either 100 ml or 1000 ml (depending on the activity of the adsorbent for removing paraquat). Next, to 10 ml of this diluted solution was added 2 ml of 0.2% sodium dithionite color developing solution. The developed blue color was read immediately in a spectrophotometer at 395 mμ. The higher the percent paraquat removed from solution the greater the protection given by the adsorbent.

The third phase of this experiment was conducted using Amberlite resin which was shown to be the most effective adsorbent in the second phase of the experiment. The method used to obtain the data was the same as that used in the second phase of screening.

RESULTS AND DISCUSSION

Table 1 summarizes the results of initial screening for 25 different adsorbents and indicates which were most suitable for further study. The list includes a number of readily available pharmaceutical or household materials as well as a few adsorbent materials commonly found in chemistry laboratories. Eight of the more promising adsorbent materials, plus one additional material not used in the initial screening, were compared in the second phase of the experiment. As can be seen in Table 2, Amberlite CG-120 resin showed much greater adsorptive capacity for paraquat in simulated gastric juice than any of the other materials. Removal of paraquat from the experimental gastric juice was over 99% with this adsorbent as compared with 59.7% for an equal weight of the material next in efficiency.

A more thorough evaluation of the activity of the Amberlite resin was carried out in the third phase of the experiment. Results are shown in Table 3. Amberlite CG-120, 200-400 mesh, was used because of its slightly better suspending properties than the 100-200 mesh type. It has about equal effectiveness with the 100-200 mesh type as an adsorbent. The volumes of 2 to 30 ml of paraquat concentrate used in this part of the experiment were amounts considered to be in the range of what a human being might accidentally ingest. The volume of 5 ml is commonly accepted for a teaspoonful and 15 ml for a tablespoonful. The amount of Amberlite resin required to effectively neutralize the paraquat was varied in order to find the greatest percent removed with the least amount of adsorbent.

The results of this study indicate that, of the materials tried, Amberlite CG-120, either 100-200 or 200-400 mesh, is the most promising adsorbent for study on experimental animals. A limited amount of exploratory animal work at this laboratory has shown the Amberlite resins to be effective in reducing tissue levels compared with nonprotected animals and, in some cases, there was indication of protection against poisoning.

Use of trade names is for identification purposes only and does not constitute endorsement by the Environmental Protection Agency.

TABLE 1

Paraquat Adsorption Screening Test

Adsorbent	Final Concentration[a] of Paraquat in Gastric Solution ($\mu g/ml$) x 10^3	Percent Paraquat Removed from Gastric Solution
Amberlite CG-120 (ion exchange resin, 100-200 mesh)	0.03	99.4
Res-Q, universal antidote[b]	0.03	99.4
Amberlite CG-120 (ion exchange resin, 200-400 mesh)	0.05	99.1
Magnesium Trisilicate, U.S.P. powder	0.05	99.1
Charcoal, Norit A	0.07	98.6
Charcoal, Coconut (activated, 50-200 mesh)	1.05	81.2
Florisil, P.R. grade	1.34	74.6
Nuchar Attaclay	2.50	53.2
Gelusil, tablets[c]	2.74	48.3
Silica Gel G (grain size 10-40μ)	4.79	9.7
Alumina, activated (Alcoa Type F-1, 60-80 mesh)	4.79	9.7
Kaopectate, liquid	4.92	7.2
Soil, sandy loam	4.92	7.2
Aluminum Oxide G (grain size 10-40μ)	4.99	5.8
Alumina, absorption (80-200 mesh)	5.09	4.0
Charcoal, animal, powder	5.16	2.6
Jello	5.16	2.6
Soil, potting (high humus content)	5.16	2.6
Pectin	5.18	2.3
Chromosorb W, DMCS-A/W (60-80 mesh)	5.19	2.0
Milk of Magnesia, tablets	5.19	2.0
Silicic Acid (325 mesh)	5.19	2.0
Sand, mortar	5.28	0.3
Milk of Magnesia, liquid	5.30	0.0

[a]Values were determined by taking a 1/100 dilution of the original paraquat and gastric solution, developing the color with sodium dithionite and reading the optical density at 395 mμ. Calculations were based on a standard recovery curve. Determinations were run in duplicate. Initial concentration of paraquat in the simulated gastric juice was 5.3 x 10^3 $\mu g/ml$.

[b]A universal antidote for accidental poisoning containing activated charcoal, magnesium hydroxide, and tannic acid.

[c]A pharmaceutical preparation containing a mixture of magnesium trisilicate and aluminum hydroxide, ratio 2:1.

TABLE 2

Paraquat Gastric Adsorption by Selected Materials

Adsorbent	Final Concentration of Paraquat in Gastric Solution (μg/ml) 1 x 1000 dilution[a]	Percent Paraquat Removed from Solution[b]
Amberlite CG-120 (100-200 mesh)	20[c]	99.3
Amberlite CG-120 (200-400 mesh)	25[c]	99.1
Res-Q (universal antidote)	1.25×10^3	59.7
Charcoal, Coconut (50-200 mesh)	1.6×10^3	48.4
Magnesium Trisilicate (U.S.P. powder)	1.75×10^3	43.6
Charcoal, Norit A	1.95×10^3	37.1
Gelusil, tablets (finely powdered)	2.2×10^3	29.1
Florisil, P.R. grade	2.55×10^3	17.7
Kaolin (hydrated aluminum silicate, N.F. colloidal)	3.1×10^3	0.0

[a]These values were determined by taking a 1/1000 dilution of the original paraquat and gastric juice mixture, developing the color with sodium dithionite and reading the optical density at 395 mμ. Calculations were made from a standard recovery curve.

[b]Average of three values. Initial concentration of paraquat in the simulated gastric juice was 3.1×10^3 μg/ml.

[c]For both the Amberlite resin adsorbents only a 1/100 dilution was needed to obtain a measurable reading in the spectrophotometer.

TABLE 3

Paraquat Gastric Adsorption Using Amberlite

Volume of Paraquat Concentrate (ml)	Amount of Amberlite Adsorbent (gm)	Initial Amount of Paraquat Cation (gm)	Final Amount of Paraquat (gm/ml of dilution)[a]	Percent Removed[b]
2	5	.471	.0065[c]	98.6
3	5	.707	.014[c]	98.1
4	5	.942	.045[c]	95.2
5	5	1.18	.115	90.3
6	5	1.41	.253	82.1
8	5	1.88	.566	70.0
9	10	1.88	.138	92.7
10	5	2.36	1.14	51.4
10	10	2.36	.26	88.8
10	15	2.36	.088	92.3
10	20	2.36	.038	98.4
15	10	3.53	.007	66.5
15	15	3.53	.003	86.4
15	20	3.53	.0014	93.4
30	20	7.05	.013[d]	64.4
30	30	7.05	.007	80.8
30	40	7.05	.0038	89.4

[a]Dilution 1/1000 except where noted otherwise.
[b]Average of three values.
[c]Required a dilution of 1/100.
[d]Required a dilution of 1/10,000.

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