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INFLUENCE OF ASH FROM COAL GASIFICATION ON THE PHARMACOKINETICS AND TOXICITY OF CADMIUM, MANGANESE AND MERCURY IN SUCKLING AND ADULT RATS

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ABSTRACT

Solid waste from coal gasification plants in the form of ash or slag represents a relatively new environmental hazard whose impact on health is not yet known. It contains several trace elements which might constitute a health hazard and might also interact with the metabolism and effect of other toxic metals already present in the human environment.

We therefore studied the pharmacokinetics and toxicity of cadmium, manganese and mercury in adult female rats which received ash in the diet (5%) over a period of five weeks and in suckling rats whose mothers were given ash in the diet throughout the period of pregnancy and lactation. Radioactive isotopes ^{115m}Cd, ^{54}Mn and ^{203}Hg were administered orally or intraperitoneally to determine the intestinal absorption and body retention of these metals. The toxicity of cadmium, manganese and mercury was determined in three different age groups of animals treated with ash for five weeks before a single oral administration of these metals as chlorides. The LD_{50} values were calculated by the method of moving averages eight days after administration.

Suckling rats showed a higher intestinal absorption of all metals and a higher toxicity than adults but almost no differences between the ash treated and control group. The pharmacokinetics and toxicity of cadmium, manganese and mercury in adult rats was also practically not affected by the dietary treatment with ash. These data do not indicate serious interactions of ash from coal gasification with cadmium, manganese or mercury at simultaneous exposure.

The gasification of coal is expected to provide a major source of energy in the near future. There are a number of methods that can be used for coal gasification and one of the practical and feasible ones is the Lurgi process. This process is used in the production of synthetic gas in Yugoslavia at the REMHK "Kosovo" plant near Priština. The potential health effects of this and similar procedures are not yet known and a detailed toxicological evaluation of such effluents is therefore required.

The aim of this work was to evaluate whether ash (slag) i.e. solid waste from coal gasification influences the metabolism and toxicity of cadmium, manganese and mercury. Ash is a mixture of elements toxic as well as essen-

tial[5,8] which may interact with the metabolism and toxicity of several metals. This might be important since the health effect of cadmium, manganese and mercury present in the environment is already a matter of general concern and any potentiating effect of gasifier solids might increase this hazard.

In our present work we used two experimental approaches: pharmacokinetic studies to determine the influence of ash on absorption and retention and toxicity studies to establish the effect of ash on the acute toxicity of cadmium, manganese and mercury in rats.

Our results indicate that ash from coal gasification has no influence on the pharmacokinetics and toxicity of these elements.

METHODS

Animals

The experiments were performed on albino rats of different ages from the Institute's breeding farm. Sucklings were kept with their mothers in litters reduced to six within one day after birth. Older animals (16 and 52 week-old males and females) were kept in plastic cages with stainless steel bottoms in groups of 6 – 12 animals per cage. During the pharmacokinetic studies rats were kept in individual metabolic cages.

Diet

The experimental diet was prepared by adding 5% of gasifier ash to our standard rat diet. The method used for sampling and treatment of ash as well as analytical data for the ash sample are presented elsewhere[5,8]. Ash analysis shows the following macro- and micro-components per 100 g of ash: Ca – 29 g, Si – 11 g, Fe – 8 g, Mg – 5.5 g, Al – 3.7 g, Na – 0.8 g, K – 0.3 g, Ti – 0.3 g, S – 0.2 g, P – 0.12 g, Mn – 0.12 g, Cr – 9 mg, Cu – 7.6 mg, Zn – 5.6 mg, Pb – 2.4 mg, Cd – 0.1 mg. The experimental and control diets were pelleted in the same way in the "Pliva" Pharmaceutical Works, Zagreb (producers of our control diet).

Rats were on the diet with ash additive for five weeks in pharmacokinetic and six weeks in toxicity experiments. Sucklings were exposed through their mothers which received the diet with ash additive over the period of pregnancy and lactation.

Pharmacokinetic experiments

The pharmacokinetic part of the experiment was performed in 576 rats: 288 adult females and 288 sucklings. Half of the animals were fed on the diet with ash additive (5%) and the other half was on control diet. Adult females were 20 weeks old and sucklings one week old at the time of radioisotope administration. Rats were divided into three groups receiving ^{115m}Cd, ^{54}Mn or ^{203}Hg respectively. Radioisotopes were administered orally or intraperitoneally one week before the end of the five-week exposure period.

All radioisotopes were supplied from the Radiochemical Centre, Amersham, England. For oral administration of radioactive isotopes to sucklings we used the artificial feeding method[7] and to adult rats administration of radioisotopes by stomach tube (in 1 ml of distilled water). Intraperitoneal administration was performed by injection (in a volume of 0.02 ml to sucklings and 1 ml to adults).

The specific activity of ^{115m}Cd was about 0.7 mCi/mg Cd. The oral dose contained 15 μCi in sucklings and 60 μCi in adult rats. The intraperitoneal dose contained about 10 μCi in sucklings and 20 μCi in adult rats. The specific activity of ^{54}Mn was >100 μCi/μg Mn. The oral and intraperitoneal dose was about 3 μCi in both age groups. The specific activity of ^{203}Hg was 0.5 mCi/mg Hg. The oral dose was about 3 μCi and the intraperitoneal about 2 μCi in both age groups.

The whole body retention of radioisotopes was determined six days after oral or intraperitoneal administration in a twin crystal sodium iodide scintillation counter (Tobor, Nuclear Chicago). The results are expressed as percentage of the administered dose and presented as arithmetic means and standard error of the mean.

Toxicity experiments

Toxicity testing was performed in three different age groups of animals: in two-week-old sucklings and in 20 and 52-week-old adult rats of both sexes. There were 1 080 animals in the whole experiment. Half of the animals i.e. 540 rats were exposed to 5% ash in diet for six weeks. The toxicity of each metal was tested in 360 rats eight days before the end of the dietary treatment period.

Animals received cadmium ($CdCl_2 \cdot H_2O$), manganese ($MnCl_2 \cdot 4H_2O$) or mercury ($HgCl_2$) by stomach tube in a volume of 0.5 ml/100 g body weight. Six dose levels were used for testing the toxicity of each metal in each age and sex group. Six animals were used for testing each dose level i.e. there were altogether 36 experimental and 36 control rats aged 2 weeks (both sexes); 72 experimental and 72 controls (36 males and 36 females) aged 20 weeks and 72 experimental and 72 control rats (36 males and 36 females) aged 52 weeks used.

The LD_{50} values were calculated by the method of moving averages[11] eight days after a single oral administration.

RESULTS

Pharmacokinetic studies

After oral administration in adult animals the retention in the whole body of all metals was very low (0.1 – 1.2% of the oral dose). The results were almost the same in control animals and in rats on diet with ash additive (Table 1). In suckling rats whole body retention of all metals was much higher (36 – 79% of the oral dose). Again the values obtained in the control and ash treated group were practically the same.

TABLE 1

The effect of ash additive to diet on the whole body retention of radioactive cadmium, manganese and mercury after oral administration (% dose 6 days after administration). Results are presented as arithmetic means of 12 rats ± S.E.M.

Group		Control diet	5% ash diet
Adult females	^{115m}Cd	0.59 ± 0.04	0.81 ± 0.15
	^{54}Mn	0.18 ± 0.01	0.10 ± 0.01
	^{203}Hg	1.20 ± 0.30	1.26 ± 0.44
Sucklings	^{115m}Cd	38.46 ± 3.38	36.31 ± 1.82
	^{54}Mn	79.29 ± 1.49	78.87 ± 1.55
	^{203}Hg	56.30 ± 1.82	51.76 ± 1.43

After intraperitoneal administration the retention of all radioisotopes in the whole body was much higher (Table 2). Again the retention in sucklings was higher than in adult rats, but only by a factor of about 1.1 for cadmium and about 1.6 for manganese and mercury compared to very high differences in relation to age observed after oral administration of these radioisotopes. No difference between the control group and the ash treated group was found.

TABLE 2

The effect of ash additive to diet on the whole body retention of radioactive cadmium, manganese and mercury after intraperitoneal administration (% dose 6 days after administration). Results are presented as arithmetic means of 12 rats ± S.E.M.

Group		Control diet	5% ash diet
Adult females	^{115m}Cd	82.6 ± 0.7	81.2 ± 0.7
	^{54}Mn	50.7 ± 0.9	47.8 ± 1.2
	^{203}Hg	52.8 ± 1.8	55.0 ± 0.7
Sucklings	^{115m}Cd	92.8 ± 1.7	91.4 ± 2.9
	^{54}Mn	82.4 ± 1.8	82.6 ± 2.8
	^{203}Hg	91.0 ± 1.2	84.4 ± 2.9

Toxicity studies

LD_{50} values for cadmium were age dependent. Lowest values were obtained in sucklings, indicating higher toxicity in the youngest age group. The results were independent of the dietary treatment. No differences related to sex were noticable (Fig. 1). The toxicity of manganese was also practically independent of the diet and sex of the animals and less influenced by age of the rats than for cadmium (Fig. 2). The toxicity of mercury was also highest in sucklings and was independent of ash additive to diet and sex of the animal (Fig. 3). It might be concluded that oral toxicity of cadmium, manganese and mercury was not

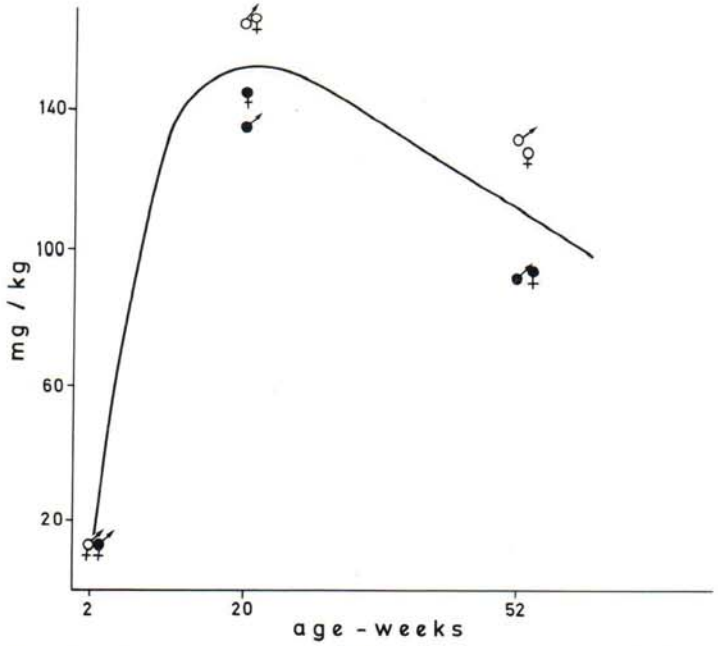

FIG. 1 – LD_{50} values eight days after oral administration of cadmium ($CdCl_2 \cdot H_2O$) in mg/kg for rats of both sexes in relation to age and dietary treatment; open circles – controls; solid circles – animals treated with 5% ash in diet.

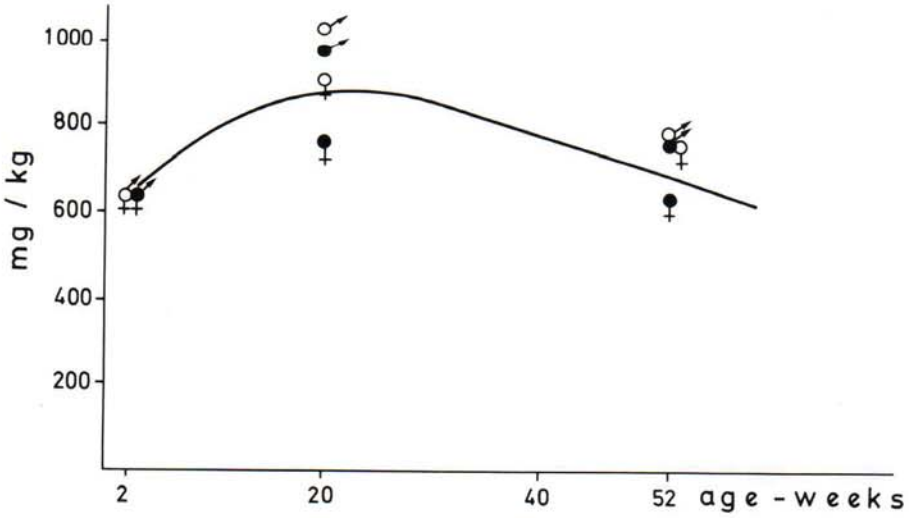

FIG. 2 – LD_{50} values eight days after oral administration of manganese ($MnCl_2 \cdot 4H_2O$) in mg/kg for rats of both sexes in relation to age and dietary treatment; open circles – controls; solid circles – animals treated with 5% ash in diet.

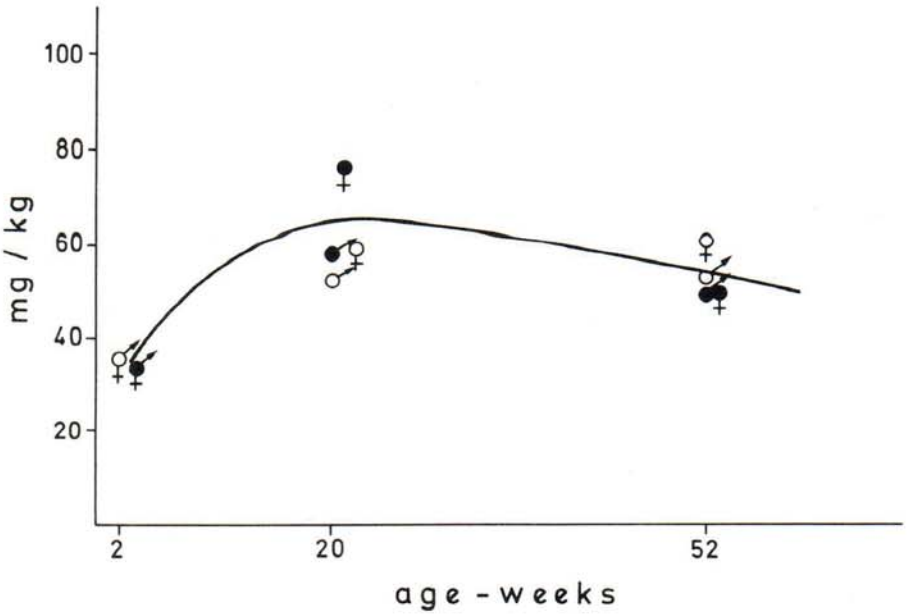

FIG. 3 – LD_{50} values eight days after oral administration of mercury ($HgCl_2$) in mg/kg for rats of both sexes in relation to age and dietary treatment; open circles – controls; solid circles – animals treated with 5% ash in diet.

influenced by ash additive to diet or sex of the animals and was generally higher especially for cadmium in sucklings than in other age groups of animals.

DISCUSSION

It is known that high calcium and iron content of the diet might reduce absorption of several toxic metals[10]. In our experiments addition of 5 per cent of gasifier ash to our rat diet which contains about 1.2% calcium and 0.06% iron increased the calcium content by a factor of about two and that of iron by about seven[5,8]. However, our diet with ash additive caused practically no changes in the pharmacokinetics of cadmium, manganese and mercury. The reason might be the complex interaction of toxic and essential metals contained in the ash in the gastrointestinal tract; already high calcium and iron content of our control diet and/or the poor bioavailability of metals from the ash.

It is also known that pretreatment with low doses of metals can cause a reduction in the toxicity of metals most probably by induction of metallothionein synthesis[2,3]. The reason why the pretreatment of animals with the complex mixture of metals as contained in ash did not influence the toxicity of cadmium, manganese and mercury could be the same as that used in explaining our pharmacokinetic result i.e.: complex interactions, bioavailability etc.

The important conclusion from these experiments is that gasifier ash is not likely to potentiate the health effect of several toxic metals. Our other results indicate that the addition of ash to the diet causes only some reduction in body weights[8] and cortical bone indices[1], but otherwise produces no changes in other health effect parameters like blood values, urinary protein excretion, trace element concentration in organs or histopathological findings[5]. All this indicates that gasifier ash is not likely to produce serious health effect in concentrations higher than expected in the environment.

Our present results show age related differences in the metabolism and toxicity of cadmium, manganese and mercury, which indicate that sucklings might be at a higher risk than adults at the same level of environmental exposure to these metals. The reason for it is a higher intestinal absorption and oral toxicity of metals in the youngest age group. This conclusion is in agreement with our previous data[4,6] and the results obtained by other authors[9].

We believe that the approach used in our present experiments could be used as a "model" for studying the interaction of mixtures of elements, as contained in environmental samples, with a known toxic element which is of general concern as an environmental pollutant.

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