

The
Danger of Food Contamination
by Aluminium

(THIRD EDITION)

With critical analysis of J. H. Burn's Report for
the British Non-Ferrous Metals Research Association

BY

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PREFACE.

At the end of last year when I had been working on this subject for nine months, I showed the result of my work to some leading lights of the Profession of long experience, and on whose judgement I could confidently rely. After carefully weighing the evidence they regarded the matter of such vital and far-reaching importance that they urged me not to act too hastily, but to bring it out through recognized and authoritative channels.

I therefore approached the Royal Society of Medicine, but their programme was already filled up to the end of this year, and they suggested my applying to the *Lancet*. This Journal was not prepared to print my Paper, the *Practitioner* could only offer me space for a totally inadequate 1,700 words, and the *British Medical Journal* was equally out of court, owing to previously expressed opinions.

The professional and scientific world being thus denied the opportunity of having the other side of the case adequately presented to it, it became obvious that the peril to the health of civilized humanity as a whole must continue, *for this could only be countered by authoritative medical and scientific opinion insisting on the removal of the danger.*

The peril being a very real and very urgent one, I felt I had no alternative but to make these facts known independently and without further delay, to my brother Medical Practitioners, to enable them to exercise their own individual judgement.

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THE DANGER OF FOOD CONTAMINATION BY ALUMINIUM.

THE following paragraph appeared in the February, 1931, issue of *The Journal of the Institute of Hygiene*, p. 169: "The German Federal Bureau of Health has made a laborious investigation into the effect of aluminium upon the body, and found no disturbances when men were given larger doses of aluminium than would be involved in ordinary abrasions from cooking utensils. It was found that the metal ingested did not enter the body fluids from the intestine but was carried off without absorption. The Bureau, therefore, reiterated its opinion, expressed in 1893, that aluminium vessels could be used with perfect safety for kitchen and household purposes."

Here we have a definite unequivocal statement, by apparently a high scientific authority, and if the findings are absolutely correct, and convey the truth, the whole truth, and nothing but the truth, well and good. Humanity can henceforth use this substance in ever-increasing quantities with perfect impunity and with the absolute assurance that no possible harm can in any case result. But in pure justice to the vital and far-reaching importance of this matter, and for the sake of generations to come, let us examine these statements with the greatest possible circumspection before fully and finally accepting them as irrefutably true.

Observations on the *immediate* effects of a substance, however "laborious," do not convey all its potentialities, and it should be very carefully noted that this particular

investigation has been wholly confined to "the aluminium which would be involved in ordinary abrasions from cooking utensils," i.e., to its "metallic" and only its "metallic" form. Can this be justly called a true, laborious, and unbiased research into the whole question of food contamination from this substance? The investigation the *Lancet* itself made in 1913, on the other hand, from which I shall presently quote, shows most laborious and painstaking research, and deals mainly with the forms of aluminium which are chiefly found in foods cooked in these vessels, viz., the hydroxide and a soluble form of the metal, the latter being in comparatively small amount as compared with the former. Metallic aluminium also comes off and has to be reckoned with, but in very small amount, unless of course the pan has been scraped during the process of cooking. Yet this latter is the only one dealt with by these German savants. One wonders whether this was intentional or an oversight.

No mention is made by these foreign investigators of the length of time they expended over their "laborious" work, but I doubt if they can claim a full year as I can. My attention was first unwittingly directed to this matter by the following case.

On March 24 last year a lady of middle age was sent to me by her local medical attendant with recurrent gastric attacks, which had been increasingly frequent of late. So much so, indeed, that he had arrived at the conclusion that the appendix was involved and that operation would be advisable. The symptoms took the form of pain, like red-hot bands, round the epigastric region, coming without warning and with an intense feeling of "stiffness." An associated slight rise of temperature was the rule, and several days were spent in bed during each attack.

The last attack had occurred ten days before, after a month's interval. It came on at 8 p.m., while at dinner, with shivering and a temperature of 100.6° F. All night, she said, she was in agony, which continued unabated

till next day, when its intensity gradually lessened. The bowels this time continued regular, though one previous attack had been preceded by diarrhoea.

By palpation I could find no cause for the attacks, there being no abnormal tenderness, or other signs, in the gastric, pyloric, hepatic or appendix areas, and the pelvic organs were normal. Suspecting some poison entering with the food, and thinking of possible copper contamination from the cooking vessels, I questioned her, but was assured that she had always been most careful as to the cleanliness of her cooking vessels, and *had used nothing but aluminium*, having recently bought an entirely new set. Her insistence on "nothing but aluminium" being used set me thinking, only to reject any suspicion of this metal on the ground that she had enjoyed very good health in the past, though using this all the time, and had felt quite well between the attacks. Still, to prove the matter to my own satisfaction, I stopped her using this metal for cooking, and allowed none of it to touch her food or drink, but I made no other change in her diet or general mode of life. *The attacks then and there ceased and she regained perfect health.*

I fully realized at the time that this might be put down to coincidence, but the case of a relation of mine, which I had shortly after this, was so significant that I was forced to regard this metal as the cause of the trouble. This lady, who was in middle life, had suffered in the past with pyloro-duodenal attacks, which I had relieved for fairly considerable intervals; but they had a tendency to recur, and this one had proved peculiarly difficult to cope with. It took the form of sore, bruised sensations in the epigastrium, and occasionally also in the abdomen generally. An intense burning "as of rawness" was felt from the mouth down to the stomach, the tongue itself feeling so raw that it was impossible to take hot tea or other liquid. Concomitantly, intensely acid risings were experienced, which, together with the pain, were almost invariably relieved by taking food. Other associated symptoms were the sudden awakening with a feeling of

suffocation or strangulation (frequently quite independent of the gastric symptoms), intense palpitation and great fear, and drenching perspirations. She would get up and drink some water and pant so violently from the effect that she would have to sit down. Then she would get back to bed and sleep till morning, no second attack ever occurring in any one night. In addition, she had sudden and entirely unaccountable and uncontrollable attacks of vomiting, which seized her at odd times and any time. Sometimes food and sometimes a fluid like hot water would come up, frequently being suddenly ejected in a stream like a fountain. Several days, or only one day, might intervene, but no more than one attack occurred in any one day. "Ptyalism" was an invariable precursor of the attacks, which might come equally whether she were out of doors or at home. In each case, and however awkward the situation, the impulse to vomit had to be instantly obeyed.

As only aluminium vessels were, and had been for a long time, used for cooking, it occurred to me that this might be the cause of the trouble, though the symptoms differed considerably from those previously noted. I therefore stopped all use of this metal, *with immediate relief and no return of the symptoms from that time to this*, except on a few rare occasions after dining, or partaking of food, away from home, when a mild recurrence would remind her of her former trouble. That is to say, she has been to all intents and purposes completely free for a whole year, and it is very certain that no arguments would ever convince this patient of the truth of the German dictum that "this metal ingested did not enter the body fluids, but was carried off without absorption."

I need not say that these cases set me thinking very seriously, but I saw at once that to publish such cases then would be of little real value, and that I must consider these as only the starting point of prolonged research to prove conclusively whether my first deductions were right or wrong. General inquiries elicited the following facts:—

(1) When water is boiled in an aluminium vessel, a black deposit forms over the portion of the vessel in contact with the water. If fruit is afterwards stewed in this same vessel this deposit disappears, the metal becoming quite bright again.

(2) These cooking pots have a reputation for being very easily cleaned, but the cloth used for this purpose becomes very black. This is because being so soft a metal the surface actually comes off every time, leaving a fresh surface below.

(3) Officers in Kenya Colony had suffered violent gastric attacks from putting lemon juice into their aluminium water bottles, and Fortnum and Mason were now supplying them with bottles lined with nickel. The native boys out there refused to have their food cooked in aluminium pots recently supplied, preferring to carry infinitely heavier iron ones for miles.

It became obvious that I had to ascertain:—

(1) Whether the metal came off during cooking, and in what form.

(2) If so, was any of it introduced into the body in a soluble form, or did it remain insoluble, and consequently incapable of absorption into the system?

(3) What was the nature of the black substance given off?

For this purpose I sought the help of Dr. Eastes, of the Pathological and Public Health Laboratories in Harley Street. He took a keen personal interest in the tests, and I am greatly indebted to him for the extreme care and precision with which he had them carried out.

Shortly after this I ascertained that similar tests to which I have already referred had been carried out by the *Lancet* in 1913, but they were not quantitative, so that Dr. Eastes' tests supplement and verify them.

"LANCET" TESTS, 1913.

The vessels used were purchased from an ordinary retail dealer.

(1) The first test, that of boiling water in an aluminium

saucepan, was apparently negative, no soluble aluminium salt or suspended particles of oxide being found, though some chemical change was found in the slight discolouration of the metal, which lost its lustre. Here, be it noted, no mention is made of how long the water was boiled in the vessel, though we know how cooks frequently allow kettles to continue boiling uselessly on stoves for hours, filling them up from time to time with more water to make up for that loss.

The negative result of this test is inexplicable in view of Dr. Eastes' recent definite positive findings with boiling water, but of this more anon.

The next test, however, amply shows how dangerous it is to allow water to come into contact with aluminium, especially if left for some time.

(2) When cold water was left in the saucepan for twenty-four hours, a *white gelatinous substance seceded from it, which on examination proved to contain alumina and silica.*

(3) A 1 per cent. solution of common salt in tap-water gave a similar result, for when left overnight after boiling for several hours "*several white gelatinous growths on the edge of the fluid were noticed where the aluminium was in contact both with the salt water and the air.*" These growths contained alumina and silica.

(4) A 1 per cent. solution of acetic acid, as representing household vinegar, when boiled for several hours gave a negative result, but no mention is made of the solution having been left standing overnight in the vessel.

Dr. Eastes' analyst recently made a test with a similar solution for me, and found "a distinct amount of aluminium."

(5) *Common salt and acetic acid, presumably in the same proportion as above, when boiled several hours were found to contain traces of soluble aluminium salt. On leaving the pan in contact with its contents and in the cold for a night "some soft white aluminium rust appeared in several places, and the metal was pitted."*

(6) Similarly with *tartaric acid*, which occurs in many

fruits and vegetables, when previously boiled and left at rest for twenty-four hours, "*produced patches of white aluminium rust.*"

(7) With *common salt and tartaric acid* the saucepan remained clean and "apparently unaffected, but on testing the fluid, traces of aluminium salt were found."

(8) With *citric acid* the same results were obtained as in No. 7, and after several hours left in the cold "there were signs of the aluminium being attacked" but no mention of the quantity found is made. So I decided to have a separate test made with diluted lemon juice in view of the Kenya officers' experiences. The result of this I will give later.

(9) *Carbonate of soda* (which, by the way, cooks frequently add to vegetables). *Even with so weak a solution as 1/10 % the aluminium was found to be affected, the surface of the saucepan showed distinct darkening, and the solution responded DECIDEDLY to the tests for the metal.*

It is here noted that "it is desirable to exclude alkaline soda salts in cooking operations in which aluminium vessels are used, and that it had been noticed that in the price lists of aluminium goods the warning was generally issued that soda should not be used." It is an unfortunate fact that such warnings are apparently not given at the present time. When a complete set of such vessels was ordered by my family from a well-known store in Oxford Street some two or three years ago, no written or verbal warning was given with them, and recently when a saucepan was purchased from an ironmonger in the North of England, the purchaser was verbally advised not to clean it with soda, but *no mention was made as to the use of soda when cooking.* Then again at a small ironmongers near Wimpole Street, inquiries elicited from the assistant that "they sold practically nothing else but aluminium for cooking nowadays, that he had heard that lemon was a fine thing to clean it with, and that a bit of soda added to improve the colour of the vegetables does the pan no harm." Not a word, be it observed, of

any harm to the customer!! Added to which, cooks, as a rule, take no heed of any warning of this kind when given, and many of them I find are unaware of any danger, and are in the habit of adding common washing soda freely when cooking vegetables; so much being frequently added that the vegetables have a strongly alkaline taste.

(10) *Beefsteak fried*, "showed distinct traces of alumina, besides lime salts."

(11) *Tomatoes, butter, salt and pepper also fried*—showed slight indications of soluble salts of aluminium.

(12) *Soup prepared in an aluminium saucepan*, consisting of beef extract, carrots, onions, salt, pepper and vinegar, mere traces of alumina were found.

I wish this result specially noted as it does not fully coincide with Dr. Eastes' tests, which I will give you later.

Onions and carrots individually boiled produced negative results, but

Brussels sprouts showed "traces of aluminium"; when, however, a little carbonate of soda was added, as is usual with this vegetable, "there were signs of the metal being attacked, and aluminium was found in small quantities in the liquor," showing that vegetables do not prevent the corrosive action of carbonate of soda.

The liquor of apples boiled also gave a small quantity of aluminium.

It is here noted as not advisable "to leave water for long in aluminium water bottles," and that "it may be desirable also not to scour cooking vessels to such an extent as to remove any thin coating which forms on the surface, for this coating subsequently becomes protective."

An additional precaution advised is to "keep the vessels perfectly dry when not in use, and coat them with a film of hydrocarbon oil to protect the metal from the combined action of moisture and air." These precautions are no doubt excellent, but one wonders what the use of a water bottle is which you cannot keep water in for long, and where one is to find a cook who will purposely leave

her vessels unscoured and will coat them with oil whenever she puts them on one side.

Incidentally, the War Office informs me that they have discontinued the use of aluminium water bottles for some years now.

It might reasonably be thought that the above tests were all sufficient, but Dr. Eastes and myself were anxious for more recent confirmation of the more important findings, and for the greater accuracy of quantitative analyses. The pan used was one of the best and most expensive procurable, and one which had been used in my own household for a considerable time.

DR. EASTES' TESTS, 1930.

(1) 1,000 c.c. London tap water was allowed to stand in the saucepan twenty-four hours.

Results.—The total amount of materials detached or sweated from the pan was 2.45 gr. per gallon of water.

The substances consisted of alumina, silica and iron.

(2) Nature of the blackening found after boiling 1,000 c.c. tap water in the saucepan for twenty minutes and allowing to cool.

The resultant liquid was cloudy and, on standing, a considerable amount of a white voluminous precipitate was deposited. After filtering, the water was found to contain the merest trace of metallic aluminium, but the white precipitate consisted of a compound of calcium and alumina. Silica was present and a trace of iron.

The darkening was due to iron impurities in the aluminium being exposed when a surface of aluminium was removed. Hence plain water boiled twenty minutes does definitely contain alumina, and though the dark deposit does not itself consist wholly of aluminium, it is an indication of this metal coming off the vessel.

(3) On heating milk in an aluminium vessel a considerable amount of material was taken up by the liquid, which represented 140 GR. PER GALLON, the greatest part of the material dissolved or detached was aluminium.

This, mind you, without allowing it to remain some time afterwards in the vessel, as is the habit with many who boil milk in a saucepan overnight and let it stand till the morning.

(4) When *gooseberries* were stewed in the saucepan the metal was readily attacked, as much as 31 to 85 GR. PER GALLON being taken from the material of the pan.

(5) *Rhubarb* similarly treated gave 7.7 gr. per gallon.

(6) A sample of lemonade was made in the saucepan using three lemons and 500 c.c. of ordinary water. This liquid attacked the saucepan readily, 25.6 gr. per gallon being dissolved, which readily explained the Kenya officers' attacks.

(7) A soup of mutton, potatoes, onion and carrot and 0.5 grm. of salt was made and allowed to stand twenty-four hours.

I had this test specially made as it had come to my knowledge that it is a common custom for soup to be left overnight in the pan in which it is cooked. The result was absolutely dumbfounding, the action being so intense (though no alkali or acid had been added) that as much as 300 gr. per gallon of metal was taken from the saucepan. *Imagine then what an appalling quantity must come off if soup is not only left overnight, but heated up again, and this is repeated for many days, as I am informed is by no means infrequently done.*

I would like to emphasize the point that the normal traces of aluminium existing in the materials cooked was allowed for in the experiments carried out by Dr. Eastes' analyst. In the soup test, for example, a preliminary examination showed that a small amount of aluminium was present in the original materials from which the soup was made, and this was deducted from the final figures.

To make assurance doubly sure, I had a soup with similar materials made in an enamel saucepan, no additional aluminium being found in this case.

It is clear from the above experiments that the metal enters the food as the hydroxide and as a soluble salt,

and we know that the metal itself becomes detached, so that we have these three forms to reckon with. Next as to what happens to it in the stomach.

As long ago as 1888 Professor J. M. Mallet published a Report on Baking Powders in the *Chemical News* of December 14 of that year, in which he described having made an artificial gastric juice containing 2.5 gr. HCl and three parts pretty easily soluble pepsin in water to produce 1,000 parts of the liquid. In this solution 50 gr. of aluminium hydroxide was allowed to stand with occasional shaking at the temperature of the human body (98°-99° F.) for two to two and a half hours, and although the acidity of this solution was so feeble, it nevertheless dissolved from 47.3 to 61.8 per cent. of the aluminium hydroxide, and in addition was found to precipitate from 5.6-14.5 per cent. of the pepsin. Aluminium phosphate similarly tested gave slightly smaller figures for "solution," and higher figures for "precipitating" the pepsin, but both readily dissolved this aluminium salt, and in cases of hyperchlorhydria (with more HCl present) the amount dissolved would naturally be very much higher.

Not satisfied with this, I had this test repeated by Dr. Eastes' analyst, who found that 100 c.c. of a similarly prepared gastric juice dissolved 0.11 grm. = $1\frac{1}{2}$ gr. of aluminium hydroxide, thus proving once and for all that *aluminium hydroxide is not an insoluble salt so far as the human organism is concerned.* As it was obvious that an appreciable quantity of the metal itself entered the food when the vessels were scraped, or rubbed, during the cooking, I had a similar test carried out with the actual metal scraped from the pan. This gave 0.18 grm. = 2.7 gr. dissolved by 100 c.c., i.e., *the metal is actually more soluble in the stomach than the oxide.*

All the above tests show that pepsin in no way retards the well-known solvent effect of HCl on aluminium hydroxide and on metallic aluminium; the solution formed being of course chloride of aluminium.

Professor Mallet's tests also showed the additional inhibitory effect of aluminium on digestion by the precipitation of some of the pepsin.

Seeing that it was well known years ago that aluminium was soluble in HCl, and that this acid is a natural secretion of the stomach, it is an enigma why the danger to the human organism of taking salts of aluminium into the stomach has been hitherto overlooked.

It now became necessary to ascertain whether this soluble aluminium became absorbed and its effects on animal tissues. I found considerable light on this in the August 1928 number of the *Journal of Hygiene*, containing a reprint of the laboratory findings of Georges Schaeffer, G. Fontes, E. Le Broton, Ch. Oberling, and L. Thivolle of Strasbourg University in connection with alum baking powders, which are used very extensively in the U.S.A., though forbidden in England, France, Germany, and many other countries (alum being, of course, a double salt of sulphate of aluminium and an alkaline sulphate).

After first proving that aluminium phosphate contained in these powders becomes soluble in the stomach, they fed for four months:—

Group 1.—Twenty couples of mice with ordinary bread made with yeast.

Group 2.—Ditto, with the same bread to which aluminium phosphate had been added.

Group 3.—Ditto, the same bread, but raised with alum baking powder.

All the latter two groups which introduced aluminium into the systems of the mice when submitted to anatomopathological examinations showed serious lesions of the digestive tract varying only in intensity in different individuals. I quote from the Report:—

“The most common of them is a paracellular necrosis of the superficial epithelium of the stomach, and of the tops of certain intestinal villi. The necrosis can be brutal, and attack not only the epithelial layer, but also the vascular tissues of the papillary axis. These erosions resemble greatly erosions met with in human pathology. With

EXPERIMENTS BY GEORGES SCHAEFFER, G. FONTES, E. LE BROTON,
CH. OBERLING AND L. THIVOLLE, OF STRASBOURG UNIVERSITY.

20 Couples of Mice fed for 4 Months.

GROUP I.	GROUP II.	GROUP III.
Bread made with ordinary yeast	Same Bread, to which Alum phosphate had been added	Ditto, but raised with Alum baking powder
Subsequently—		Subsequently—
Digestive tract found NORMAL.	Serious lesions of digestive tract found, mainly in Pyloro-duodenal Area	
300 Offspring.	193 Offspring.	71 Offspring.
Death-rate of these in 1st week—	Death-rate of these in 1st week—	Death-rate of these in 1st week—
6 per cent.	10 per cent.	28 per cent.

4 Days similarly fed for 3 to 4 Months.

Subsequently—

Lesions in the large intestine, especially in the Descending Colon and Sigmoid Flexure.

certain mice one of the lesions is found to be situated on the pylorus, the other a few millimetres away in the duodenum; a loss of superficial substance characterizes these lesions; the epithelium is replaced by a necrotic fibrous magma containing a few polynuclear leucocytes. This necrosis can be important; situated in the fundus of the stomach, they often penetrate in depth, leucocytes having penetrated around the necrotic centres. *One never sees lesions with the mice, Group 1, fed on the same bread, but leavened with yeast. They are specific, and due to the formation of soluble aluminium salts in the digestive duct.*"

What more complete confirmation of one's own human clinical findings so far as the pyloro-duodenal area could one possibly obtain? Equally significant evidence as to the large intestine is found in four dogs fed similarly for three to four months, in which *there were distinct lesions in the large intestine, especially in the descending colon and sigmoid flexure.* The congested, adenomatized mucous membrane, covered with mucus, was visible to the naked eye. Histological slides showed intense congestion, together with small subcutaneous hæmorrhages, superficially localized; in some places submucous œdema was noticeable.

These same observers proved the fact that the soluble salts formed in the digestive tract were absorbed into the system by quantitatively estimating the amount of aluminium in the internal organs following on similar experiments by Gies and Steel, but they ascribed still more importance to their proof of marked delay of growth in chickens and rats similarly fed, with otherwise perfectly balanced diets rich in vitamins, and they also found a significant effect on "reproduction." For example, in the group of mice already quoted, Group 1 had 300 offspring, Group 2 (with aluminium phosphate added to the bread), 193, and Group 3 (with alum leavened bread) only 71, i.e., less than a quarter produced by mice

on normal bread. The death-rate of the offspring in the first week was respectively 6 per cent., 10 per cent., and 23 per cent., i.e., *the alum-leavened bread mice had a death-rate four times as great as those on yeast bread.* I have given you the essentials of this Report, but it should be read in its entirety for its full significance to be assimilated.

Frank P. Underhill and F. I. Peterman, of Yale University, have also conducted a most careful series of experiments on animals which were reported in the *American Journal of Physiology* of September, 1929. I can here only give a fraction of their findings, but choose the most outstanding. With 20 per cent. solutions of chloride and sulphate of aluminium the single lethal dose for rats was found to be 7 to 8 gm. per kilo, causing death in one to three days. With guinea-pigs 5 to 7 gm. per kilo proved fatal in three to seven days (when given as an initial dose of 3 gm. and 1 gm. on alternate days). In rabbits an initial dose of 4 to 5 gm. and 1 gm. on alternate days, of either the chloride or sulphate, caused death in seven to eleven days, the immediate effect being loss of appetite, inactivity and depression, and the post-mortem changes mainly consisting of general visceral congestion, *pinpoint hæmorrhages in the gastric mucosa,* and in some cases *small greyish ulcers in the intestinal mucosa.* Necrotic changes were found in the liver of guinea-pigs and rats, while the *kidneys of rats, guinea-pigs, and rabbits all showed degenerative changes, the epithelium of the convoluted tubes showing necrosis with frequent granular casts.*

They quote the findings of Roth and Voegthlin who fed rabbits and cats on aluminium tartrate and sodium aluminium lactate and found that 20 mg. per day proved fatal to the former in two months and 40 to 80 mg. per day to the latter in three to seventeen days. Dogs fed on 20 mg. a day died in four months. The symptoms noted were diarrhoea (in cats, alternating with constipation), loss of appetite and weight, and albuminuria, and the changes noted varied from *congestion of the gastro-*

EXPERIMENTS BY P. UNDERHILL, F. I. PETERMAN AND ANTHONY
SERRANO, OF YALE UNIVERSITY.

SINGLE LETHAL DOSE.

RATS.	GUINEA-PIGS.	RABBITS.
7-8 grm. per kilo.	5-7 grm. per kilo	7-8 grm. per kilo
(in a single dose)	(in initial dose of 3 grm., and 1 grm. on alternate days)	(in initial dose of 4-5 grm., and 1 grm. on alternate days)
Death in 1-3 days	Death in 3-7 days	Death in 7-11 days

POST-MORTEM CHANGES FOUND.

General visceral congestion, pinpoint hemorrhages in the gastric
mucosa, SMALL GIBBING ULCERS in intestinal mucosa.

Necrotic changes in Liver (in Guinea-pigs and Rats).

Degenerative changes in Kidneys (in Guinea-pigs, Rats and Rabbits).
Epithelium of the Coiled Tubules showing necrosis, with frequent
granular casts.

FRANK P. UNDERHILL AND F. I. PETERMAN,
OF YALE UNIVERSITY.

Traced out six cases of ACUTE POISONING IN MAN, since 1843, from a
large dose of an Aluminium Salt.

Symptoms: Frequent Vomiting; Acceleration of Pulse; Tremor, followed
by Weakness; Depression; and sometimes Coma and Death.

STORAGE OF ALUMINIUM IN THE ANIMAL
BODY.

Brain holds more per 100 grm. of tissue than the:—

Liver, which comes next in importance.

Kidney.

Spleen.

Rest of Body, including muscular tissue, collectively hold an impor-
tant amount.

Mainly EXCRETED IN THE BILE, which holds eight times the quantity in
the blood.

intestinal tract to corrosion and hemorrhagic areas, as
well as congestion of the liver, kidneys, and spleen.

They have traced out half a dozen cases of acute
poisoning in man since 1843 from a large single dose of
an aluminium salt, usually on alum, the symptoms being
frequent vomiting, acceleration of the pulse, tremor
followed by weakness, depression, and sometimes coma
and death.

These reports prove conclusively that aluminium not
only enters the blood and tissues of the animal organism,
but that it acts deleteriously on the body generally. The
next question "whether, having entered the tissues it is
immediately thrown off entirely when the supply is
stopped, or whether it is cumulative"? is answered by
the further experiments of Frank P. Underhill and F. I.
Peterman, who have amply proved not only that it is
stored, but in addition have determined the relative
proportional amounts taken up by the several tissues, and
shown how it is eliminated.

Using the sensitive Alizarine test they found it chiefly
in the liver, brain, kidney and spleen, and that it was
mainly excreted in the bile, which holds eight times the
quantity of the blood. Its peculiar affinity for nervous
tissue is shown by the fact that the brain holds a larger
store per 100 grm. of tissue than the liver, and more than
5½ times as much per unit as the blood. Muscular
tissue generally holds relatively small amounts, but
when the total mass of muscular tissue in the body is
considered the total aluminium stored in this may reach
an important figure. Their researches amply show that
aluminium, though found in animal organisms, is not
essential to those organisms, that it is a foreign substance
which is being continually eliminated, that such elimina-
tion puts a strain on the organism, and that when more
is forced upon the system than it can deal with disastrous
results follow.

The above experiments taken collectively leave no room
for doubt that we all, every one of us, have this substance
stored in our bodies and that we are constantly throwing

off the excess. That this unceasing elimination must be a strain, and that this strain is proportional to the amount taken in, is only common sense.

During the last year I have fully satisfied myself that every one of us is affected to some extent by this state of things, and that the lessening of the intake is followed by improved health. Taking myself, for example, I was generally regarded as an example of good general health, but I must have suppressed what I regarded as trifling or unavoidable disabilities, for stopping aluminium has resulted in the loss of the following:—

A compressive waking headache which for some years past had made work in the morning a great effort. *Marked sensitiveness of the gums, with a feeling of looseness of the upper teeth on compressing the jaws.* An unaccountable tendency to *subluxation of the knee-joints*, for the previous two years or so, when either foot met some unevenness in the ground.

I do not say these were caused by the metal, but they have all left me for the last year, and I have been decidedly better mentally and physically. It is an interesting point that as long as six months after I had stopped all sources of entry of aluminium into my system, Al_2O_3 0.11 and 0.15 per cent. were found on the only two separate occasions an examination of the feces was made.

Is there any wonder that the German scientists "found no disturbances when men were given larger doses of aluminium than would be involved in ordinary abrasions from cooking vessels," these men being already full of the substance and sufficiently healthy to throw off this slight addition?

I have so many cases illustrating this matter that I hardly know which to choose, but the following are fairly typical:—

A lady, aged 47, and of dark complexion, had suffered from rheumatic arthritis of the non-deformans type for some time, which had been pronounced by her medical attendant as progressive and incurable. The joints mainly affected were the knees, ankles, feet, arms,

and shoulders, with at times, *locking of the knees* (I wish this symptom specially noted), these being in association with mucous colitis. She came with an exacerbation of the symptoms, which she put down to climatic changes, on *May 15, 1930*, the pains were then fairly general, the knees as usual taking precedence, a marked feature of these being *stiffness* after rest, and *acute tenderness over the internal semilunar cartilages*. She expressed her suspicion of the abdominal origin of her troubles, owing to the associated *pains in the caecum* which had been notably worse of late. These she described as running down the right side of the abdomen to the spot where her appendix was removed in 1928, the bowels having been more constipated of late.

On closely questioning her as to the latter, I elicited the fact that she had for years past been conscious of a marked *want of expulsive power in the lower bowel*. Chronic post-nasal catarrh had been a notable feature for many years, and an irritable burning sensitiveness in the eyes (recently also over the forehead) with eczematous spots, of a seborrhoeic character, affecting the scalp and right eyebrow. She complained also of back-ache and bearing down. Her diet had been very reasonable, consisting of fish, chicken, salads, fruit and vegetables, meat and sugar being taken very sparingly, but all her cooking for years past had been in aluminium, the milk had been boiled in an aluminium saucepan, and the kettles were composed of this metal. All this was stopped.

May 29, 1930 (a fortnight later).—*Rheumatism slightly better*, but she still has it all the time. *The abdominal trouble has, however, enormously improved*; she had hardly felt it at all the last seven to ten days, and the bowels now act more freely. The old necessity for straining, involving prolongation of the usual time, is still there, but *there is definitely more power in the rectum than formerly*. She regarded this as very remarkable, seeing that she had suffered in this way for years. *The back-ache and bearing down are also very much better.*

She then volunteered this interesting information: "For the last year or two, one of my maids, aged 38, has had very bad indigestion. She has been for ever complaining of the awful pain in the upper part of her stomach. Time and again she has had to go to the doctor for medicine, which has relieved her temporarily, but the pain has invariably returned. She is taking nothing for indigestion now, but since the aluminium cooking has been stopped she is decidedly better. The type is an empty indigestion, and she has to have something to eat or drink in order to obtain relief."

Here we have the same duodenal symptoms cropping up again.

June 18, 1930 (i.e., three weeks later).—*Is ever so much better. She has not felt so well for a very long time. There is marked improvement in the rheumatism and sleep, there is a gradual gain in rectal power, and since the last two consultations she has felt the former dragging feeling in the right kidney area very much less. The burning over the forehead is still present, but is less, and the spots on the scalp are dying off.*

The maid, she told me, had now quite recovered, having lost all the indigestion. She said her (the maid's) former symptoms had included nausea, but no vomiting; she had tried to be sick, but failed; and the pain used to come on about two hours after food.

July 3, 1930 (i.e., fortnight later).—She had some rheumatism owing to the damp weather, but the abdominal symptoms, as well as the scalp and right eyebrow eruption and the burning in the skin of the forehead, were quite gone.

The maid continues perfectly well.

Since then she has continued in greatly improved health, and now no longer requires any treatment.

In May, 1930, a young lady (with a history of three attacks of so-called appendicitis eight years before, not operated on), had lately been suffering from pains in the caecal region from time to time, together with a moist scabby eruption at the back of the scalp, of a

seborrhœic character and covering an area of half-a-crown. This latter had proved very persistent, though it had improved to some extent under treatment. She now came with epigastric pain, following on fatigue, strain and responsibility, associated with a sinking sensation, and relieved by taking food. There were also pressive, blown-out feelings, unrelieved by eructations, and examination discovered marked tenderness over the pyloric area. Though mitigated by ordinary remedies and care with regard to her meals, these symptoms continued till I stopped the use of aluminium cooking vessels. *The stomach symptoms immediately ceased, and the eruption cleared up in a fortnight.* Since then, up to the present time, there has been no return or even threatening of the trouble, and together with an absolute freedom from all caecal trouble.

Another case worth mentioning was also of a young lady, suffering from debility associated with a parietic condition of the caecum. This was evidenced by local fullness and tenderness, and "experimental enemata" (given after the bowels had acted) bringing away a quantity of material held up in the caecum. She, like the former case, improved under ordinary treatment up to a point, but the loss of power in the caecum continued till I stopped all aluminium cooking. *Expulsive power returned to the caecum very shortly after this, as proved by the absence of fullness and tenderness and the failure of the experimental enemata to bring away anything more than the normal discoloration of water.*

I have given the name "Experimental Enemata" to those used immediately after an apparently normal action of the bowels, to differentiate them from the usual irrigations to clear the intestine in the ordinary way.

It is interesting to note in this case, in view of others which I have had, that some long-standing pains round the *right shoulder-joint*, which interfered with piano-practice, and a *burning pain at the inner edge of the right scapula*, which had been felt from time to time, both cleared up at the same time.

This last October a young professional nurse came to me with a history of gastric attacks and loss of weight. They commenced four years ago, necessitating discontinuance of her work for three months. Shortly after resuming her duties, she was seized one night with severe abdominal pains and vomiting. Appendicitis was diagnosed, but an emergency operation discovered the appendix perfectly healthy, the surgeon being unable to account for the symptoms.

Successive attacks followed (without vomiting at this time), and a diagnosis of visceroptosis and gastric dilatation was made with the help of X-rays, but gastric lavage in skilled hands and Plombières douches failed to help matters. A strict diet of milk and water in a nursing home was then tried with decided benefit, but directly she came out of the home and resumed ordinary diet all the symptoms returned. She saw several specialists and obtained some comfort from a Curtis belt, but the attacks continued, mostly with vomiting now, much gastric flatus and constipation. She described herself as a nervous wreck, with an intense horror of leaving home to fill a new post. If she did so, she would have to starve to prevent vomiting, which any food would cause. Her memory had become defective, and she has lost 2 lb. weight in the last three weeks. *The tongue had had a heavy obstinate white coat for years with bad taste in the morning.*

As all her cooking was with aluminium, the same measures were adopted, and:—

Three weeks later she reported a wonderful improvement in the digestion, and a complete loss of flatulence. A gain of 3½ lb. in this three weeks astonished her relations, such a thing having been unknown for years past, and it is notable that an abdominal irritating rash, which had been there for a considerable time, cleared up at the same time. Though so obstinate before, the tongue had only a slight streak of fur left on it and the bad taste had gone.

She is now in excellent health and has no gastric

symptoms whatsoever except that the strain of travelling tends to temporarily upset her.

When I first began my investigations into the action of this substance I thought I had only the gastric sphere to deal with, but in a very short time I found the field spreading in ever-widening circles, till the significance of the extent of its action has reached proportions beyond anything I ever dreamed of originally. For the benefit of future investigators, and with all due diffidence, let me give some idea of its influence as traced out by myself.

Besides its irritative, inflammatory, ulcerative and parietic effects upon the gastric and intestinal mucosa, it apparently seriously deranges the nervous system. It has a strong affinity for fibrous, tendinous and ligamentous tissue, and tends to cause subacute inflammatory conditions of the gums, strongly suggesting a possible influence in pyorrhœa; my suspicions in this regard being strongly borne out by the writings of Charles T. Betts, a dental surgeon in America. The mucous membranes are affected no doubt by their action in excreting it in the course of its elimination from the body, but certain cases have led me to regard the possibility of a specific effect here also. Its skin action is extremely well marked, elimination probably having a great deal to say to this. Ample confirmation on its action in this regard came from Dr. Spira in his articles to the *Franco British Medical Review*, and to whom I am greatly indebted for his cordial assistance in putting his experiences at my disposal.

Complaint may be made that my indictment is too comprehensive, and it has been suggested that I ought to have confined it to the gastro-intestinal sphere, but this would not have been fair to future workers in this field, and would only have delayed them in their investigations. I therefore felt in duty bound to record my own personal conclusions as fully as possible.

The fact that aluminium is found widely distributed in nature is no argument that in quantity it is innocuous.

It certainly is so found, in minute quantities, but, as Dr. Eastes says, "so is arsenic"; nevertheless, we would not from choice imbibe this latter poison into our system, day in and day out, in ever-increasing quantities, and expect no harm to follow. One scientist has gone so far as to maintain that the life itself of the animal body is actually dependent on the presence of aluminium in it, but this is definitely and finally refuted by F. P. Underhill and F. I. Poterman, already referred to, who, using tests capable of detecting the remotest trace of the metal, prove that it is not found in the foetus, and that the young animal tissues remain free from it till at least three weeks after birth, at which time, in some instances, they have found traces of it in the lungs, it having been conveyed thither apparently by inhaled dust.

Granted that many sources of entry are very small and even infinitesimal, collectively they must be very seriously considered, and that this collective supply is not only steadily increasing, but has already reached dangerous proportions the following list of vessels made in aluminium will prove:—

Saucepans (and this metal has recently actually been used to line vessels made of iron, copper and nickel), preserving pans, frying pans, poachers, grillers and toasters, kettles, porridge cookers, pasteurizers, steamers and different patent cookers, cullenders and sieves, officer's canteens and water-bottles, cooking spoons, fish-lifters and fish slicers, egg slicers, ordinary spoons and forks, skewers, and actually *lemon squashers*, custard and egg whisks (from which the metal must become freely detached), coffee pots (some wholly aluminium, and others with a patent aluminium structure to fit inside vessels of other material), tea-pots, tea-infusers, milk containers of various kinds, milk jugs, water jugs and bottles, cups, tumblers (especially nests of tumblers for picnic baskets and collapsible tumblers), canisters for holding tea, sago, rice and sugar, &c., and flour dredgers, biscuit tins and biscuit boxes, pepper pots, salt cellars, mustard pots, toast forks and racks, thermos

flasks and patent caps for whisky and other bottles, patent caps for glass milk bottles to assist pouring, tooth paste tubes and tooth powder boxes and wrappings for suppositories and pessaries. To show the ever increasing growth of this evil the *Encyclopadia Britannica* gives the following startling information, "That aluminium foil is rapidly replacing tin foil for wrapping chocolates and cheeses and for tubes holding cosmetics. Steam jacketed pans are made of this metal for institutional kitchens and in *food-stuff industries*. Thin sheets for bottle and jar covers is alone an industry of no small importance. The brewing industry makes wide use of it in the form of vats and fermenting vessels, storage vessels for yeast and beer, and tanks for transport of beer by road and rail.

In Europe the dairy industry uses aluminium widely as tanks and vessels for the storage, pasteurization and transport of milk and cream, and for vats used in cheese making. For many other foodstuffs which are weakly acid aluminium finds rapidly extending use, e.g., in *jam-making, fruit preserving and meat extracting*, and the production of 'high grade' gelatines."

Just lately I find that the makers of electric refrigerators are beginning to replace the heavy metal drawers for making ice-cubes with others made of this metal, and that it is largely used in the manufacture of ice-creams, so extensively sold in the streets.

I think it will generally be accepted that the reason why, under these conditions, we are not all continually ill, and that it causes ill-effects at one time and not at another, lies in our "powers of elimination" and "acquired immunity." So long as the former are working efficiently, no obvious symptoms develop, but any cause temporarily weakening these will at once allow the system to become over-charged, and adverse effects to follow. This throws additional light on the beneficial effects of saline laxatives, and the benefits of "change of air" and "change of diet," which may often in reality be due to "change of cooking."

Not the least result of this state of affairs to be considered is its effect on "diagnosis" and "treatment" of other causes of ill-health, for, *until we can eliminate this underlying influence how can we diagnose anything clearly or treat anything satisfactorily?*

I have now put my side of the case as briefly as possible, considering the extreme gravity of the matter, and it only remains for the two sides of the question as set forth (on the one side by the Gorman declaration, and on the other by my own humble researches), to be once and for all time finally settled by the best scientific brains the country can produce.

TIDER TO SECOND EDITION, JANUARY 9, 1932.

Having been specially requested to print a few more copies of this monograph, I would like to take this opportunity of thanking those medical men who have written to me confirming from their own experience my findings with regard to the toxicity of Aluminium. The number who have cured themselves and their patients of long-standing ill-health by simply discontinuing the use of this metal for cooking is such that their massed testimony entirely outweighs any statements which are published from time to time to the effect that some observers consider it innocuous because they have given it to some animals without any apparent ill-effect. We know quite well that many human beings take it in quantity in their food, by cooking in Aluminium for years, without any apparent ill-effect, until one day something occurs to lessen their resistance. When symptoms then appear, is it surprising that Aluminium remains unsuspected as the cause of these? Yet it frequently *is* the cause, and it is this very fact which accounts for its remaining unsuspected so long.

But to return to animals. Has anyone, in justice, the right to put aside the observations of scientific observers such as I have quoted, working at a well-known University, month in and month out, and finding definite lesions produced in animals? Each of these observers individually vouches for, and puts his signature to, such findings, having convinced himself of their reliability and genuineness before publishing them to the world.

The obvious answer to the above question is "No." So we have the most reliable testimony that, under some conditions at least, and in some particular animals, irritative, ulcerative, and generally poisonous, effects are produced, and it is a simple matter for any genuine and earnest clinical observer to fully satisfy himself that similar effects are produced in human

beings. But if they are *ever, at any time*, produced, this ought alone to justify us in *never* allowing any Aluminium, under any circumstances, to enter our bodies from artificial sources. Why, even the suspicion that it *might* be poisonous ought alone to be sufficient. However, this state of things has been allowed to continue and to grow for so long, that evidence of very marked deleterious effects is necessary before humanity as a whole will rise up and demand freedom from this "tyranny." I use the word "tyranny" because, as things are, no one can escape from it. The mere stopping of Aluminium cooking in his own home is not enough; he is bound to imbibe it elsewhere.

There is already an abundance of the evidence required, but one cannot have too much. Therefore, I shall be very glad to hear from any more of my brother Medical Practitioners who have experience of the action of Aluminium on their own, or their patients', bodies.

One word more. I have heard on the best authority that although Aluminium is largely used for cooking utensils and coverings for foods and bottles, &c., the amount thus used is but a fraction of that employed in Engineering and the Arts, &c.; therefore, no one is going to be ruined by the abandonment of the former. I also place the greatest reliance on our staunch British integrity and good feeling, being quite convinced that when once those in charge of our great Aluminium Industries are fully satisfied that this metal is dangerous to the health of their fellow-man, they will lose no time in taking steps to make the necessary alterations in their machinery.

RIDRR TO THIRD EDITION, AUGUST, 1932.

IN reprinting this brochure one is tempted to make considerable additions, but to do so would be to detract from its chief merit of "brevity." It was designed originally to induce other medical men to test the matter for themselves, and arrive at their own deductions. Those who have done so have apparently all come to the same conclusions as myself. There are a few however who, for reasons best known to themselves, make no such tests, and ignore those recorded by others, preferring to assume an attitude of incredulity, and basing their antagonistic arguments on laboratory evidence. One such is J. H. Burn, who is responsible for a report recently issued by the British Non-Ferrous Metals Research Association, apparently for trade purposes, entitled "Aluminium and Food." I would like every medical man interested in this subject to read this summary of evidence, for there will be few who will not be astonished at Dr. Burn's final deduction from it, *viz.*, that "Aluminium cooking vessels offer no danger to health," the more so when they themselves have cured many of their own patients, of long-standing, otherwise intractable ill-health, by stopping the use of such vessels.

Let me briefly review the evidence as Dr. Burn gives it. The first quotation in *Group I* (Experiments by Official Bodies) is from an investigation made for the Prussian War Office as long ago as 1891, when the decision to use aluminium for soldiers' water-bottles and cooking utensils, was under consideration. To begin with, tests were made on rabbits with sodium aluminium tartrate, "young rabbits, about half to three-quarters grown," being selected for the purpose. Here, at the start, the fallacy of any deductions made from such experiments becomes obvious, for even if we allow that indications of the action of a substance on the human body can be obtained from animal experiments, it is obvious that such experiments should approximate as closely as possible to the conditions as we find them in human beings. But it is not the young, growing, human beings whom we find visibly affected by the ingestion of aluminium, so that even if some observers say they find

no visible effect upon the growth and appearance of young animals this proves nothing.

The next quotation is that from experiments made for the U.S.A. Department of Agriculture in 1914, which were to test the effect of "alum in foods," but here again the value of the test was nullified by only healthy young men being experimented upon. We know ourselves how young people laugh at the idea of aluminium being injurious; their bodies are well able to throw it off, and they apparently suffer no injury, though I have good reason for believing that their organisms are under considerable strain while doing so, and that they ultimately suffer in consequence. I have found injury—almost wholly confined to individuals in advanced life, but one occasionally comes across it in the younger generation, as, for example, in the chauffeur, aged 21, whose case I showed with others on July 29, to members attending the recent British Medical Congress in London.

Group II deals with "individual experiments," and in the (a) division (viz., "By those who conclude that in certain circumstances the consumption of Aluminium compounds is harmful.") Under this heading are quoted the investigations of:—

(1) *Steel* who found "that aluminium passes into the blood in considerable amounts from alum in the diet," when given to dogs.

(2) *Shroffer, Pontés, Le Breton, Oberling and Thivollo* (1923), which my readers have already become familiar with in this Monograph, and which alone furnish conclusive proof that under some conditions, at any rate, aluminium produces very grave effects on the animal organism. In extent, time involved, and the care with which they have been carried out, these experiments are far ahead of any which claim to find no ill effects in animals.

(3) *Siebert and Wills* (1929) are next quoted as experimenting on rabbits and finding *degenerative effects in the Blood, Kidneys and Liver*, and they conclude their investigations by asserting that "There would seem, therefore, to be no doubt concerning the possibility of the absorption of aluminium following the injection of aluminium compounds, even when in the form of the supposedly insoluble $Al(OH)_3$, since blood changes occur similar to those following the direct introduction of aluminium into the blood stream";

In the (b) division ("Experiments which suggest that, on the whole, Aluminium in food is harmless.")

(1) *Siem*, under Professor *Myer* (1886), gave sodium aluminium tartrate to cats for four weeks, causing initial diarrhoea, but no after effects were noticed. Here no mention is made of the age of the cats, and the experiment is only over a period of four weeks. He found the hypodermic injection of the same salt caused death in seven to fourteen days in rabbits, dogs, and cats, which admitted its toxicity under certain conditions, even at such remote dates as this!

(2) *McCollum, Bask, and Becker* (1928) experimented on growing rats, and recorded no autopsies, so their findings are valueless.

(3) *Myers and Mull* (1928) studied the distribution of aluminium in rats and found a slightly higher percentage in the liver and brain in those fed on 0.002 grain Aluminium per rat. There is no mention, however, of their having made any examination of the intestines, or other organs, for pathological changes.

(4) *Myers and Morrison* (1928) found that the liver of dogs fed with aluminium had an average of 0.27 mg. Al per 100 g. tissue, as against 0.15 ug. in control dogs, but they found no more in the spleen, kidneys or heart, which is contrary to the findings of *Underhill* and *Peterman*, which apparently were made on other animals.

(5) One wonders how *Dr. Burn* can put these same observers (*Underhill* and *Peterman*) under the (b) division when it is admitted that they found (in 1929) that "Aluminium is promptly absorbed in small quantities following a single feeding of food to which it has been added. It continues to be absorbed when Aluminium rich diets are fed for various periods of time." "It circulates in the blood and is stored especially in the Liver, Brain, Spleen and Thyroid" and "the bile is the chief excretory path for Aluminium."

(6) *Mackenzie* (1930 a and b): This investigation (on pigs) is vaguely obscure as regards the production of "anæmia." It also deals with the amount of aluminium recovered in the fæces; an investigation which is not of much help, as it is practically impossible to make it absolutely accurate, and it gives no assurance that some, at least, of the aluminium so recovered was not

temporarily absorbed into the blood-stream, and subsequently re-excreted into the intestine. Added to which the tissues of the animal experimented on may already be saturated with this substance. In the cases of these experiments also no post-mortem examination is reported. The same remarks apply to Mackenzie's experiments on rats. Lastly in *Group III*, Dr. Burn deals with the amount found by Mossatch (1929) to come off in different foods when cooked in aluminium cooking vessels. This investigator, like the *Lancet*, proved definitely that it did come off in measurable quantities.

That is all that matters. Different observers with different makes of aluminium vessels may find different quantities given off, but the question we have to decide is: "*Is ANY aluminium given off by any aluminium pot, at any time under ordinary everyday methods of cooking, and if so is this injurious?*"

No one now doubts that it is given off, and that owing to modern conditions, and the absence of any idea in the past that it might be harmful, also to reiterated assurances, from interested quarters, that it is innocuous, this quantity has been, and still is, increasing; the number of foods and drinks which come in contact with the metal being ever constantly augmented. That it is harmful is amply proved, and can be constantly re-proved, by anyone who cares to do so, on his sick acquaintance, by stopping aluminium cooking and watching the effects. No proof could be better than this. *This is the final and absolute proof of proofs, because it evidences the effect on the human body.* Yet Dr. Burn puts aside all such evidence, provided by myself and other medical men (as for example the cases which have been recorded in the *British Medical Journal* of late), with no better argument than that such evidence is a figment of the imagination and consequent on suggestion; weakly likening it to the imaginary benefit derived from inactive patent medicines—and the incantations of witch doctors !!!

This then is how Dr. Burn arrives at his final deduction, already recorded. He can only exonerate aluminium by shutting the door on the only evidence that really matters.