

Abductive Reasoning in the Historical Development of Communal Water Fluoridation

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A PREAMBLE —

At the turn of the century in 1999, the Centers for Disease Control and Prevention (CDC) published a list of the ten greatest public health achievements in the United States during the 20th century (1900–1999). Among those given were vaccination, the control of infectious diseases, the recognition of tobacco use as a health hazard, and the communal fluoridation of drinking water, the topic of immediate interest to us. The summary CDC statement regarding fluoridation reads as follows:

Fluoridation of drinking water began in 1945 and in 1999 reaches an estimated 144 million persons in the United States. Fluoridation safely and inexpensively benefits both children and adults by effectively preventing tooth decay, regardless of socioeconomic status or access to care. Fluoridation has played an important role in the reductions in tooth decay (40%-70% in children) and of tooth loss in adults (40%-60%).

It is hard to reconcile this type of public health accolade with the current battle being waged against fluoridation in many cities across the United States. For example, in the author's present hometown of Santa Fe, New Mexico, fluoridation began in 1955 but was slated

for termination by a vote of the Santa Fe City Council in 2012. Fortunately, the elimination of fluoridation was averted by opposition from the County of Santa Fe that jointly oversees water distribution for the area. A news report from the local newspaper documents the Santa Fe City Council's aborted push to end fluoridation, and provides some of the fallacious reasoning behind that attempt. We will return to a few of these faulty bits of reasoning against fluoridation after the complete news item is provided below:

SANTA FE CITY COUNCIL VOTES TO STOP ADDING FLUORIDE TO WATER SUPPLY

Source: The Santa Fe New Mexican — July 11th, 2012 — By Julie Ann Grimm

The city of Santa Fe will discontinue its longstanding practice of adding fluoride to municipal drinking water.

The City Council late Wednesday amended the city code to stop fluoridation and require water managers to monitor naturally occurring fluoride so it doesn't exceed the maximum level recommended by federal standards.

The city has added the mineral to its water supply since 1955 because of the belief that it helps reduce tooth decay.

Today, the city fluoridates by measuring small amounts of a dry chemical compound at its water treatment plant on Canyon Road and at wells, and the same practice takes place at a treatment plant for Rio Grande water drawn into the joint city/county Buckman Direct Diversion project. But, following Wednesday's City Council vote, that practice will cease.

"What's happening is you are fluoridating 100 percent of the water, and anywhere from 95 to 99 percent of it does not get ingested," said Councilor Chris Calvert. "So you are basically dumping most of it into the environment one way or the other.

Calvert, who said he did graduate research on fluoride, said the city should give the \$32,000 it currently spends on fluoridation to local dental clinics for the poor.

Ten people testified during Wednesday's public hearing to appeal to councilors to halt fluoridating. They cited research they say shows that ingesting fluoride is dangerous to human health.

"It's time for the city of Santa Fe to recognize that the application of fluoride is outdated," said Jimmie McClure, a chiropractic physician in the city. He noted that fluoride is shown to be effective to prevent decay when applied topically, but not when ingested.

Another speaker, Helen Oates, called fluoridation "one of the greatest scientific frauds done to the unsuspecting public."

Other speakers asked the city to keep fluoridating.

"There are people who want Santa Fe to stop fluoridating water, and I think that's a terrible idea," said Dr. Jessica Brewster, a dentist at La Familia clinic who noted that she

was not speaking on behalf of the medical center. “It’s the most vulnerable, the poor and the uninsured who will suffer the most.”

Five other dentists also spoke at the hearing, making similar arguments. Rudy Blea, of the state Office of Oral Health, said Santa Fe is experiencing an increase in tooth decay among Hispanic youth and that maintaining fluoridation is “a good health policy.” Without fluoridation, he said, the problem is likely to worsen.

According to the state Environment Department, Santa Fe is one of only two cities in the state that adds fluoride to its drinking water system.

U.S. Environmental Protection Agency officials have announced they intend to lower the recommended level of fluoridation in public drinking water sources to 0.7 parts per million. The current standard ranges between 0.8 and 1.2 ppm. The city’s water sources have a naturally occurring level of between 0.2 and 0.4 ppm, and managers add fluoride chemicals to raise the level to a target of 0.8 systemwide.

Councilor Peter Ives said his sole “no” vote – to continue the practice of fluoridation – was based on personal experience and on the idea that the city’s adding fluoride will help vulnerable citizens, he said.

Voting in favor of the ordinance change along with Calvert were Councilors Bill Dimas, Patti Bushee, Ron Trujillo, Chris Rivera and Carmichael Dominguez. Councilor Rebecca Wurzburger was absent for the vote.

“Back in 1955, Phillip Morris was very strong on smoking too ... Until we found out later that cigarettes are poisonous and killing a lot of people,” Dimas said. “I’ve studied this issue a lot before coming here tonight, and I’ve reached my conclusion that we don’t need to add any more fluoride to our water.”

Mayor David Coss didn’t vote because there was no tie, but Coss said he “heard the dental community loud and clear ... ask us not to do this.”

“If we don’t think the [Centers for Disease Control and Prevention] is a credible scientific organization, then I guess we don’t,” he said. “They say this is a safe level of fluoride and we believe this is just not true.”

Most of the arguments just given in the *Santa Fe New Mexican* news report that are against fluoridation are statements of someone’s opinion without evidence, or are attempts to falsely equate fluoridation with other circumstances assumed to be bad just on their face. Thus, we have Chris Calvert arguing that fluoridation is just dumping environmental pollutants (obviously, a bad thing) because not all of the very minimal amount of fluoride used in communal water fluoridation is directly ingested by people. We might note that even ingested fluoride is excreted well by animals including humans; also,

it is a little disingenuous to label fluorine a “pollutant” since it is a chemical element with an atomic number of nine that appears naturally in the environment in various forms and amounts in ground water, the oceans, soil, the atmosphere, and so on. Moreover, it is comical to argue that everyone should believe Chris Calvert because he says he has done graduate research on fluorine and therefore can confidently say that the current cost of fluoridation (\$32,000 annually) would be better spent by just giving it to the poor. What is not discussed is the now heavily documented reduction in dental caries among children, whether coming from poor families or not; there is a big drop in dental disease and expense resulting from communal fluoridation that far outstrips the minimal cost of such fluoridation.

The opinions of Helen Oates and Jimmie McClure, the oddly titled “chiropractic physician,” are best characterized as benignly ignorant; the comments of the councilman Bill Dimas which equate without any justification the ills of tobacco smoking with fluoridation might be labeled as maliciously ignorant. Based now on some hundred years of data and experimentation dating from the early 1900s, it is no longer a “belief” that communal fluoridation helps reduce tooth decay and does so safely; it is as close to being an established fact of an undeniable cause and effect relationship as any natural phenomenon could possibly be.

Over the last fifty years or so, the specious arguments against fluoridation have proceeded unabated, and if anything have increased in their virulence in recent years through the mixed blessings of the internet. Once the story of how fluoridation developed has been told, we will come back to discuss some of this current opposition. But to begin our journey through the history of fluoridation, we start

with a more light-hearted introduction to the anti-fluoridation movement by quoting an interaction that appeared in the 1964 politically satiric *Dr. Strangelove or: How I Learned to Stop Worrying and Love the Bomb*. The dialogue is between Brigadier General Jack D. Ripper (played by Sterling Hayden) and Group Captain Lionel Mandrake (played by Peter Sellers):

Ripper: Mandrake?

Mandrake: Yes, Jack?

Ripper: Have you ever seen a Commie drink a glass of water?

Mandrake: Well, I can't say I have.

Ripper: Vodka, that's what they drink, isn't it? Never water?

Mandrake: Well, I-I believe that's what they drink, Jack, yes.

Ripper: On no account will a Commie ever drink water, and not without good reason.

Mandrake: Oh, eh, yes. I, uhm, can't quite see what you're getting at, Jack.

Ripper: Water, that's what I'm getting at, water. Mandrake, water is the source of all life. Seven-tenths of this earth's surface is water. Why, do you realize that seventy percent of you is water?

Mandrake: Uh, uh, Good Lord!

Ripper: And as human beings, you and I need fresh, pure water to replenish our precious bodily fluids.

Mandrake: Yes.

Ripper: Are you beginning to understand?

Mandrake: Yes.

Ripper: Mandrake. Mandrake, have you never wondered why I drink only distilled water, or rain water, and only pure-grain alcohol?

Mandrake: Well, it did occur to me, Jack, yes.

Ripper: Have you ever heard of a thing called fluoridation. Fluoridation of water?

Mandrake: Uh? Yes, I-I have heard of that, Jack, yes. Yes.

Ripper: Well, do you know what it is?

Mandrake: No, no I don't know what it is, no.

Ripper: Do you realize that fluoridation is the most monstrously conceived and dangerous Communist plot we have ever had to face?

THE STORY BEGINS —

Frederick McKay (1874–1959), the person who would become known as a father of communal fluoridation, graduated from the University of Pennsylvania dental school at the turn of the twentieth century. A year later in 1901, McKay moved west to Colorado Springs to begin a dental practice. As a person diagnosed earlier with tuberculosis (TB), McKay was heeding the common medical advice at the time for those suffering from TB to seek clean dry air and sunshine at a high altitude. It is likely that McKay’s status as a newcomer to Colorado and as part of the “lunger” community coming west “chasing the cure” that allowed him to recognize the importance of an unusual staining condition of the teeth endemic to those native to the area. This pronounced stain was not considered particularly abnormal or worrisome in the community around Colorado Springs, not even by those in the area involved with the practice of dentistry. This Colorado “brown stain,” as it was then generally called, would occupy McKay for the next thirty years before the explicit reason for its occurrence would be determined. As we now know well, the cause of this enamel staining was due to the presence of an abnormally high amount of fluoride in the communal water supply.

Over the first third of the twentieth century, McKay amassed a large body of observational evidence and some that could even be considered quasi-experimental for the conjecture that whatever was causing the Colorado brown stain, or to use the more generally appropriate term of “mottled enamel,” had to be a component of the common water supply. The various bits of information that McKay put together and then published were truly impressive, particularly since McKay’s main occupation was as a practicing dentist and not as

an academic located in a dental school. The story of McKay’s fervent interest in what caused mottled enamel and the subsequent use of fluoridation to prevent dental caries are superb illustrative examples in applied and abductive reasoning of the type developed by America’s preeminent philosopher, Charles Sanders Peirce (1839–1914), in the late 1800s and early 1900s.¹

To be explicit about the form of abductive reasoning involved in the search for a cause for mottled enamel, McKay began with the surprising observation for him as a newcomer to Colorado that individuals residing continuously since birth in the particular geographical region of Colorado Springs generally had mottled teeth. If there were something in (or, possibly, not in) the communal water supply that was unique to this specific area and which could cause the mottling, then this surprising observation of mottling would be a matter of course. So, there was reason to suspect that the communal water

¹As typically framed, Peirce’s form of abductive inference or reasoning can be phrased as follows:

The surprising fact, B , is observed
But if A were true, then B would be a matter of course
Therefore, there is reason to suspect that A is true

As an example, suppose we observe that the lawn is wet when going out for the paper in the morning. If it had rained last night, it would be unsurprising that the lawn is wet; therefore, by abductive reasoning, the possibility that it rained last night is reasonable or plausible. Obviously, abducting rain last night from the evidence of a wet lawn could lead to a false conclusion – even in the absence of rain, some other process such as dew or automatic lawn sprinklers may have resulted in the wet lawn.

Abduction is a form of logical inference that goes from an observation to a hypothesis that accounts for the observation and which explains the relevant evidence. Peirce first introduced the term “abduction” as “guessing” and said that to abduce a hypothetical explanation, say A : “it rained last night,” from an observed circumstance, say B : “the lawn is wet,” is to surmise that A may be true because then B would be a matter of course. Thus, to abduce A from B involves determining that A is sufficient (or nearly sufficient) for B to be true, but not necessary for B to be true.

The subsequent verification stages that may follow the identification of an abductive conjecture can be phrased in syllogistic terms. Assuming A represents the explanatory conjecture for our original “surprising” observation, let B' now indicate some further observation(s) or experimental outcome(s) that should be obtained if A were true. If B' does occur, then the conjecture A becomes even more plausible (and “stays in the running,” so to speak). If, however, B' does not occur, the conjecture A does not then appear to be true. This situation possibly leads to the formation of an alternative explanatory hypothesis and/or to a rethinking that A being true should have led to B' being true.

supply either had or didn't have this thing, whatever it was, and thus, mottling occurred. Evidence had to be collected at this point and in whatever form possible to evaluate the reasonableness of the water conjecture. For McKay this evidence collection meant first locating and visiting other endemic regions of mottling, all with the hope of identifying some common element or agent responsible for mottled enamel.

Some evidence was available from early on that it was probably something in the water causing the mottling as opposed to something not in the water, by noting that for an infant residing continuously in an endemic mottling area, its deciduous (or, baby) teeth were generally perfect even though later permanent teeth would show the characteristic mottling. This distinction between baby and permanent teeth suggests that a mother could dialyze out some of what may be in the water during enamel formation for deciduous teeth before being passed *in utero* to the fetus. It is much harder to believe that the mother could add something to the fetal environment to prevent mottling. Also, the analysis of the water supplies for two areas of endemic mottling could show very disparate amounts of minerals such as lime or calcium. Or somewhat conversely, for two areas where one had endemic mottling and the other did not, the water contaminants could seem very similar. The problem, of course, was in the usual type of water testing possible in the early 1900s. It wasn't until the 1930s that methods were commonly available for assessing the amount of fluoride present in the water.

McKay realized early on that he needed at least two major forms of assistance: first, some type of geographical mapping had to be constructed for the endemic regions where mottled enamel occurred;

and secondly, given the general lack of local enthusiasm for investigating what was considered a widespread but generally benign cosmetic condition, a dental expert with an impeccable national reputation had to be convinced to take an active interest.

To locate a leading dental expert, McKay had initiated on his own a correspondence with Dr. Greene Vardiman Black (1836–1915), then dean of the Northwestern Dental School in Chicago, and arguably America’s leading expert on dental enamel. Black was initially skeptical of any widespread enamel mottling as described by McKay, if only because such a condition had never appeared or been discussed in the dental literature. Nevertheless, Black accepted an invitation from the Colorado Dental Society to tour the endemic area of Colorado Springs, and then to give a summary lecture at the annual meeting of the Colorado Dental Society in 1909 as to what he had found.

A few years later and right before his death in 1915, Black in collaboration with McKay wrote a paper that appeared in *The Dental Cosmos* (February, 1916), summarizing Black’s visit to the Colorado Springs region as well as some histological studies he had done on extracted mottled teeth sent by McKay. The paper’s title is reflective of its content — “Mottled Teeth: An Endemic Developmental Imperfection of the Enamel of the Teeth Heretofore Unknown in the Literature of Dentistry.” For the purpose of summarizing the state of knowledge about mottled enamel at that time, several paragraphs from this publication are given below. Also, for later reference when the topic of communal fluoridation is under discussion, note the last comments about the general absence of dental caries even at this early date of 1916:

In the years 1906 and 1907 several dentists resident in the Rocky Mountain region told me of a peculiar condition of the teeth in certain areas in their neighborhood, which they said was not found elsewhere, and which had not been described in the literature. This condition they called mottled enamel, or mottled teeth. These men claimed that a very large proportion of those born and reared in these areas had teeth of this character. I requested that some of the teeth be sent to me for examination, and after a time (1908) I received the crowns of a number of incisors with the astonishing report that the teeth of a very large proportion of the children in the areas mentioned were of the same character.

...

It became clear to me during this superficial examination that this was a type of dystrophy of the enamel of which nothing had appeared in dental literature. Not only this, but if the statements were correct, it was endemic in type. Heretofore no endemic conditions of the teeth have been known. Further, if the reports that 87.5 percent of the children reared in these areas were afflicted with this endemic condition, the cases were numbered by thousands, and the individual deformities were of a very grave character. I went into the examination very thoroughly aroused to its importance, and in 1909 visited a number of susceptible areas and studied the conditions on the ground.

...

MOTTLED ENAMEL A NEW PROPOSITION IN DENTAL PATHOLOGY

Endemic white enamel, or mottled enamel, is an entirely new proposition in dental pathology. Nothing of the kind seems to have been discovered heretofore in any part of the world. This endemic feature gives this description unusual novelty. When I visited a number of susceptible areas during the summer of 1909 I examined the children, and many of adult age, myself. Great numbers of children seemed to be easily gathered. It was quickly seen that the reports had not been exaggerated. The settlement of these regions

is comparatively recent, and about half of the children were born and passed the earlier part of their lives elsewhere. When these were excluded, it has been found by the examination of the children in the public schools, that a little more than 87.5 per cent of those born and reared in these areas have teeth of the character described.

...

THE ESSENTIAL INJURY

The most essential injury occurring in this mottled enamel is in the appearance of the teeth and the general evil effect on the countenance of the individual. The teeth are of normal form but not of normal color. When not stained with brown or yellow, they are a ghastly opaque white that comes prominently into notice whenever the lips are opened, which materially injures the expression of the countenance of the individual. When this opaque white color is mingled with spots of brown, or a very large proportion of brown, the injury is still greater. In very many cases the teeth appear absolutely black as one sees them in ordinary social intercourse. I spent considerable time walking on the streets, noticing the children in their play, attracting their attention and talking with them about their games, etc., for the purpose of studying the general effect of the deformity. I found it prominent in every group of children. One does not have to search for it, for it is continually forcing itself on the attention of the stranger by its persistent prominence. This is much more than a deformity of childhood. If it were only that, it would be of less consequence, but it is a deformity for life. The only escape from the deformity is by the placing of crowns, and possibly of bridges or artificial dentures later in life. The proportion of the cases so bad as this is really very large. They are not all of the worst type by any means, but the struggle for a better appearance of the teeth, or the stoical endurance of a terrible affliction, is certainly upon from 30 to 100 percent of the persons being reared in the various areas where this deformity is endemic. Many of those counted as having mottled teeth are injured in such slight degree as almost to pass unnoticed. Every degree of injury, from solidly brown front

teeth to the white flecking here and there, is represented.

...

TIME OF LIFE AT WHICH THE INJURY OCCURS

One thing I wish to impress particularly upon the mind of the reader just here. Faults in the form or color of the teeth may occur from errors in growth, or may occur from causes acting upon them after the teeth have been fully formed. Any departure from the normal in the enamel of the teeth, the dentin, or the form of the teeth, from errors in development, must occur while the teeth are growing. This must be differentiated sharply from deformities that are acquired after the teeth have grown, about which more will be said later. The tissues of the teeth are not changed in anyway by physiological processes after they are once formed. This explains the fact that some teeth of an individual are found to be marked and others not, and why the incisors are more persistently marked than other teeth.

This has relation to the time in the life of the child in which the enamel in different groups of teeth is growing, having reference now only to the permanent teeth. The deciduous teeth are always normal in this respect. The permanent teeth are naturally divisible into three groups. The first group includes the first molars, the incisors, and the cuspids. The enamel of this group is growing during the first five years of the child's life, excepting that the cuspids frequently continue to the seventh year. The second group includes the bicuspid and second molars. The enamel of this group begins growing at from five to six years, and is completed at from nine to eleven. The third group includes the third molars only. The enamel of these is growing ordinarily from the tenth to the fourteenth or fifteenth year, but presenting considerable variation of the time of completion of the growth. This is an approximate statement. It occurs, therefore, that if the child is not in the locality of endemic mottled enamel during the time of the growth of the enamel of any one of these groups of teeth, that group will not be marked.

Or if a child is in the locality only during the time of the growth

of one, and elsewhere the rest of the time, only that one group of teeth will be marked. It therefore follows, that if a child born in the locality is removed and lives elsewhere for the first five years, the first molars, incisors, and cuspids will be normal. If the child returns to the locality at the end of the five years and continues to live there, the other two groups of teeth will be mottled. Having lived a part of the time in this area does not seem to carry with it a continuance of the injury after removal. Neither does living elsewhere during the growth of the enamel of the incisors, and then coming into the endemic area, prevent the injury to the teeth which have yet to grow their enamel.

Among the children examined there was every opportunity for the study of this feature of the difficulty, for among them there were many who had come into the territory at any and all periods of the growth of the enamel. By examining the teeth one could tell pretty closely the age at which they had come into the locality. This, then, expresses the general idea of the susceptibility of the different groups of teeth. Lines cannot be drawn too sharply, however, for we must remember that among those born in that region, about one in every ten persons is immune—that is, has normal teeth. This presents some very curious features. Some one child in a family may have normal teeth, while the teeth of the brothers and sisters are mottled. I saw a pair of twins, a girl and a boy. The girl's teeth were horribly brown, while the boy's teeth were normal. These two children were seen together so persistently as to occasion general remark. They ate at the same table, slept in the same house, played together, and their habits and environment had been the same since birth.

The rule is, other things being equal, that the younger the child at the time of the occurrence of any injury to the development of the enamel, the more grave the injury. According to this rule the incisor teeth are more persistently and more severely mottled than any other group of teeth. Curiously enough, however, the first molars, which have generally just begun formation of the enamel at birth,

are notably less severely mottled than the incisors, which begin the development of their enamel a little later. In the contemporaneous accretional deformities, the first molars are more severely injured than the incisors, as the rule. For all the other teeth the general rule stated seems to hold true.

...

DENTAL CARIES

As to caries, the teeth of these children compare favorably with those of other communities where endemic mottled enamel is unknown. They have a mild climate and almost continuous sunshine during the day. The children are out practically every day the year round, and this in itself certainly has its effect in limiting the amount of dental caries. But when the teeth do decay, the frail condition of the enamel makes it extremely difficult to make good and effective fillings. For this reason many individuals will lose their teeth because of caries, though the number of carious cavities is fewer than elsewhere. Yet I was of the opinion, at the end of several weeks' examination and study of the conditions, that if the appearance of the teeth could be endured, the injury in their development would, on the whole, not reduce the general usefulness of the teeth.

In preparation for the visit by Black to Colorado Springs, and as noted in the above excerpts, McKay and a fellow dentist examined the teeth of children attending the public schools in the area. A card was filled out by the parents for each child examined indicating where the child was born, when the child moved to Colorado Springs, and rather prophetically, the source of the water supply used by the child. As reported in several of the paragraphs just given from the Black and McKay paper, 87.5% of the 2945 children examined who were native to the area had mottled teeth. Although conducted a little later in 1910 and after Black's visit had occurred, McKay also examined

the students at Colorado College, located in Colorado Springs. As expected, students native to other non-endemic areas generally did not have mottled enamel, but those from Colorado Springs proper did have the characteristic staining.

In addition to the *Dental Cosmos* contribution having Black as the primary author, a second long article with McKay as the lead author appeared in the same 1916 volume but was spread over four issues. This particular paper recounted the extensive geographical search for endemic regions of mottling, primarily throughout the Southwest in Colorado, Arizona, and New Mexico. Unfortunately, this extensive study failed to identify any specific cause of mottled enamel; again, and given the inadequate chemical analyses of water then available, the culprit of fluoride could not be detected in any of the endemic areas. Several excerpts from this long McKay and Black paper follow that indicate well where the study of mottled enamel stood as of 1916:

The remarkable thing about the lesion is that it is practically, if not absolutely limited in its distribution ... to certain well-defined geographical areas, in which it occurs in the teeth of only those individuals who were either actually born and lived continuously in any of these areas during the years of enamel formation; or in those who, although being born elsewhere, were brought into such districts for a continuous residence during the years of enamel formation. These circumstances indicate that we are dealing with a developmental dystrophy, and the term “endemic” is applied because the lesion is peculiar to a district or particular locality or class of persons – natives and those coming to the locality in early childhood.

...

An endemic disease is one constantly present to a greater or

lesser degree in any place, and the investigation of this condition has left no doubt that a high percentage of those persons who conform to the conditions just set forth will exhibit mottled enamel upon the permanent teeth when they erupt. This seems to be a law pretty definitely determined, as will later be shown, as applied to all of such districts as can properly be termed 'afflicted,' 'susceptible,' or 'endemic.'

...

Mottled enamel, in my experience, has never been found upon the temporary teeth. In examining children in afflicted districts at ages when the permanent incisors and first molars have erupted, but the temporary molars are still in place, the contrast in the enamel on these two varieties of teeth is most pronounced. The white mottled enamel on the permanent teeth exhibits a marked contrast with the normal enamel on the temporary teeth, which has the customary almost bluish tinge. In explanation of this it is to be remembered that the temporary teeth are formed largely before birth, in an environment closely shielded against outside influences, with the nutritive supply dialyzed through placental osmosis. This mottled condition, in itself, does not seem to increase the susceptibility of the teeth to decay, which is perhaps contrary to what might be expected, because the enamel surface is much more corrugated and rougher than normal enamel.

...

In 1908 the work of investigation was commenced in an organized way, and the first work that seemed necessary was to locate other communities that were similarly afflicted, with the hope of finding some condition common to such localities that might be studied as the possible cause, and gradually to map out, as time went on, the entire area of distribution. This work has been steadily carried on up to the present time, and a detailed account of the examination of the various districts will be given later in the paper.

...

This case effectually disposes of the question of nationality in its

bearing upon this lesion, and emphasizes that its acquisition disregards nationality, social status, and condition of physical health—in fact, all other circumstances except the one essential, namely, residence in an endemic district during enamel formation.

When the McKay and Black papers were published in 1916, the “water supply” hypothesis may have been the dominant (abductive) conjecture for the endemic presence of mottled enamel, but it was not universally considered “proven.” We give a quote below from the McKay and Black 1916 paper that illustrates this quite well:

THE “WATER SUPPLY” HYPOTHESIS IN THE ETIOLOGY

Before continuing the account of examinations of additional territory it seems wise to digress, and take up next a consideration of the prevailing theory as to the cause of this lesion, namely, the question of water. Even from the very beginning of the notice taken of this lesion and before any definite steps were taken to study it, the sentiment of both the profession and the laity in the areas of susceptibility was that the water was in some way responsible. Indeed, it was hardly possible to mention this condition without at once encountering a question, and often a dogmatic assertion, indicating the water as the cause. Hence it has been found necessary to examine the water conditions as thoroughly as has been possible under the circumstances, as will later be shown.

Dr. Black, who has been in close touch with the investigation, has urged again and again that this water relation be followed to its very source, so far as possible, in order to eliminate it.

It wasn’t until after the publication of the McKay and Black papers that several quasi-experimental circumstances were identified, all involving changes or variations in a communal water supply that definitively showed it was something in the water causing endemic mottling. But as we now know, it would take until the early 1930s to identify fluoride as the actual responsible agent.

One of the first studies done by McKay of the effects on enamel mottling from a change in a communal water supply was in Britton, South Dakota. A dentist in the town had read the McKay and Black *Dental Cosmos* papers and contacted McKay about the same type of enamel mottling he was seeing in his younger patients but not in those who were older. McKay visited Britton in the later part of 1916, and learned that in 1898 the town had changed its communal water supply from shallow wells used up to that time, to a deep-drilled artesian well. McKay's examination of Britton's residents was conclusive: those passing through childhood before the water supply change had normal teeth; those growing up after 1898 had mottled enamel. The obvious conclusion was that the water from the newer artesian well must be at fault.

Although McKay went on to practice dentistry in New York City in 1917, he never lost interest in identifying the cause of mottling. In fact, a second occurrence of a dichotomy in the water supply, this time geographical and not temporal as it was in Britton, was soon pointed out to him by a fellow dentist practicing on Nantucket Island. A mottling/no mottling condition was present among a colony of Portuguese who had settled in Nantucket from the two small islands of Brava and Fogo in the Cape Verde Islands. Accompanied by the local dentist as a guide, McKay visited this colony and examined the teeth of those residents who permitted it. Invariably, McKay could classify whether the resident originally came from Brava (with highly mottled teeth) or from Fogo (with no mottling). The only distinction that appeared tenable between the natives were different water supplies used in the two small islands located nine miles apart.

The two most dramatic studies of the effects that a change in

the communal water supply can have on the mottling of enamel for its residents were in the two towns of Oakley, Idaho and Bauxite, Arkansas. In both instances, the results of a change in the communal water supply were prospective — the water supply change was first implemented with a follow-up some years later to see if mottling of the type seen before the change was still present thereafter. The data from Britton, South Dakota and Nantucket Island could be considered retrospective — here the communal water supply was varied or changed some time before an examination of the residents occurred. Also, in both the cases of Oakley and Bauxite, the follow-up was done after fluoride was identified as the culprit in enamel mottling. Thus, the water in both Oakley and Bauxite could be tested both before and after the communal water change. A fluoride overabundance existed before the change; minimal fluoride was present thereafter, plus an absence of any enamel mottling in the residents.

McKay had a central role in the change of the Oakley, Idaho, water supply. Originally, Oakley obtained its water from a pipeline to a warm spring built in 1908. By 1925 the mothers of Oakley were extremely dismayed by the condition of their children's teeth, particularly as compared to those having perfectly normal teeth in the surrounding areas; the matter was reported to the Director of Public Health in Boise. McKay was contacted by the health officer responsible for Oakley in 1924 and agreed to visit the town and support a change in the communal water supply through a \$35,000 bond issue proposed by the Women's Civic League. The bond issue passed based in large part on McKay's persuasive argumentation to the town. As noted by Donald McNeil in his *Fight for Fluoridation*:

“Oakley, Idaho, became the first town known to make the amazing decision to change its water supply solely because of the existence of a dental abnormality. Even more astounding was the fact that the citizens of Oakley made the decision without knowing what was in the water that caused the damage.”

McKay was not only central to the passing of the bond issue in Oakley, but also helped identify a new communal water source in Carpenter Spring nearby. Four children raised on the Carpenter Spring water all had normal enamel; and although these data were meager, it was enough to convince the Oakley officials to change to Carpenter Spring water as of July 1, 1925. Some seven years later in February of 1933, McKay examined the teeth of the twenty-four children born in Oakley since the water supply had been changed. All had normal calcification. Also, because this re-examination was done after fluoride was determined to be the causative agent in enamel mottling, a test of the old Oakley water showed 6.0 ppm (parts per million) of fluoride; whereas the new water supply had only 0.5 ppm. To get a sense of what these numbers mean, the current standard for routine community fluoridation for the prevention of dental caries is from 0.7 to 1.2 ppm; these levels are generally not enough to cause any enamel mottling to speak of.

The second major study involving a prospective change in a communal water supply was in Bauxite, Arkansas. Bauxite was a company town named for the aluminum ore mined nearby and built in 1901 by ALCOA (the Aluminum Company of America) for its employees and their families. To provide water to Bauxite, three deep wells were dug in 1909, but these were condemned in 1927 as the putative cause of severe enamel mottling in the younger residents

of Bauxite. A practicing dentist in nearby Benton, Arkansas, F. L. Robertson, was the first to report on the severe mottling occurring in Bauxite and the lack thereof in Benton, which obtained its water from the Saline River and not from deep wells.

Robertson reported his observations to the Arkansas Board of Health in 1926 regarding the severe mottling present in Bauxite and the absence of any such mottling in Benton. Upon a request from the Arkansas Board of Health, the U.S. Public Health Service initiated a survey in February of 1928 with Grover Kempf from the U.S.P.H.S. as the lead investigator and Frederick McKay as consultant. But as noted earlier, and even before the survey began, the deep wells were assumed to be the cause of enamel mottling in Bauxite, and were shut down; water obtained from the Saline River was in use by May of 1928. As might be expected by now, a resurvey of Bauxite children in 1938 showed that any new mottling was eliminated for children born after the water source was changed to the Saline River.

The Kempf and McKay survey of the communities of Bauxite and Benton was published in *Public Health Reports* (November 28, 1930) under the title of "Mottled Enamel in a Segregated Population." Several of the summary paragraphs are given below that provide the now expected survey conclusions:

The endemic area with which this report deals was reported to the Public Health Service in 1927, and centers in the town of Bauxite, Arkansas, which was established in 1901 to provide homes and a social environment for the employees of a mining company. The original supply of water for domestic purposes came from shallow surface wells and a few springs. As the population increased, a larger supply was required, and in 1909 a deep well of 255 feet depth was drilled, later augmented by two other wells close by. Wa-

ter from these wells was piped into the homes. Following this, most of the shallow wells were gradually filled, and within the community proper the deep wells were the chief source of the water supply. This deep well water has a disagreeable alkaline taste, and many of the families continued the use of spring water for drinking, especially during the warm months. The evidence collected during the examination of the children in the town school, consisting of the elementary grades and the high school, can be summarized as follows:

1. No cases of the enamel defect were found which antedated the introduction of the deep well water.

2. The oldest individual found with this enamel defect was born about the time that the deep well water was introduced.

3. All individuals in the community who had used the deep well water during any considerable period of enamel formation exhibited this defect.

4. No individual in the community whose enamel had developed elsewhere exhibited the defect.

5. Certain individuals who, although residents of the community and attending school there, but who actually lived beyond the distribution of the deep well water and depended upon the original shallow wells, exhibited only normal enamel.

Evidence supporting these postulates is presented in the tables appearing later in this report. In no district so far observed by one of the authors (McKay) has the evidence pointed so directly to a relation between the use of a certain definite water and the production of this enamel defect.

After reading the Kempf and McKay paper in November of 1930, the chief chemist of ALCOA, H.V. Churchill, became disturbed by the situation in Bauxite, particularly since opponents to the use of aluminum cookware were roaming the United States at that time denouncing the practice. Churchill hoped to show that it was *not*

bauxite or aluminum causing mottled enamel, thus depriving the opponents of aluminum with another argument against its use. A sample of Bauxite water was analyzed with a new method of spectrography that was previously unavailable to McKay. A very high level of fluoride (13.7 ppm) was present in the deep-well Bauxite water.

Churchill wrote a letter to McKay on January 20, 1931 that announced the presence of a high level of fluoride in the water from the Bauxite deep wells. In the letter McKay was also asked for additional water samples from other areas of endemic enamel mottling. McKay complied and had the various samples sent to Churchill; by March of 1931, the various endemic mottling areas showed fluoride levels that ranged from 2 to 13 ppm. Several paragraphs from the original Churchill letter to McKay are given below:

Recently we have been doing some analytical work on the Bauxite (Arkansas) water and have discovered the presence of hitherto unsuspected constituents in this water. This new revelation may have an important bearing on the dental problem not only at Bauxite but also at the other localities mentioned in your various publications on the subject.

We have discovered that the Bauxite, Arkansas, deep well water has a fluorine content of about 15 parts per million. At the present time we believe that this fluorine is present as calcium fluoride. The presence was revealed when the evaporation residue from this water was spectrographed.

...

It is worthy of note to recall that the only deposit of cryolite in the United States is found on Pikes Peak. Cryolite is a double fluoride of sodium and aluminum. Fluorides are very often found in the vicinity of volcanic activity and in those localities where hot or warm springs are encountered.

If you care to do so, we will appreciate your arranging to furnish us with waters from localities where the peculiar dental trouble has been experienced. Or possibly if you would suggest to us a list of localities where the dental trouble was common we could otherwise arrange to obtain samples. Naturally at this time we do not wish to broadcast our findings since this presence of fluorides may or may not have significance. It was our thought that possibly you could arrange to procure water samples with a minimum of publicity.

In any event, we will be glad to get your reaction to this revealed presence of fluorides in the water. There are many ways in which this fluoride content of water might function and it is conceivable that it might play an important part in the trouble being experienced.

...

We trust that we have awakened your interest in this subject and that we may cooperate in an attempt to discover what part “fluorine” may play in this matter.

Before proceeding to the consequences of identifying fluoride as the causative agent for mottled enamel, and then to the possible protective effects of fluoride in deterring dental caries, there are two additional topics that deserve mention. The first is from the early 1930s and the development of an explicit animal model using rats for the production of mottled enamel as a result of ingesting fluoride; the second is an early and perceptive discussion of mottled enamel appearing among Italian emigrants to the United States in the early 1900s. This 1901 article, appearing in the *Public Health Reports*, was written by a surgeon, J.M. Eager, of the U.S. Marine Health Service stationed in Naples, Italy. Eager was responsible for the medical inspection of ships and emigrants bound for the Port of New York in the United States.

Definitive proof of a cause and effect relationship between fluoride

and the mottling of enamel is best provided by a true experiment, possibly on animals when human experimentation is not possible or is considered unethical. At the University of Arizona and its affiliated Agricultural Experiment Station, the wife and husband research team of Margaret Smith (then head of Nutrition) and Howard Smith (an agricultural chemist) initiated a series of experiments on white rats in the early 1930s that resulted in enamel mottling of the same type observed in humans. One experiment involved feeding rats the water from St. David, an endemic mottling area near Tucson. The water was concentrated by evaporation to one-tenth its original volume; in its non-concentrated form, St. David water was found to have from 3.8 to 7.1 ppm fluoride. A second experiment involved placing sodium fluoride at differing concentrations into a rat's diet. As noted by the Smiths in a summarizing University of Arizona Agricultural Experiment Station Technical Bulletin in 1931, the enamel defects that developed in the rats "were so strikingly similar to those produced by the feeding of the residue from St. David water, that no one could fail to associate the two." In conclusion, they wrote: "Thus definite proof has been advanced to show that mottled enamel, a defect of the enamel of human teeth, prevalent in many parts of the world, is caused by the destructive action of fluorine present in the water supply of the afflicted communities."

The first appearance in the dental literature itself of any discussion of enamel mottling was from the aforementioned J.M. Eager, who contributed a short note, given below, to the March 1902 issue of *Dental Cosmos*. An earlier and expanded 1901 *Public Health Reports* entry follows this brief *Dental Cosmos* item.

From *Dental Cosmos* (March, 1902):

“Chiaie Teeth.”: Dr. J. M. Eager, of the U. S. Marine Hospital Service, reports from Naples, Italy, the frequency of a dental abnormality among the inhabitants of the Italian littoral [i.e., along the shore], and known as “denti di Chiaie,” this defect having been first described by Prof. Stefano Chiaie. This impairment of the teeth, often not amounting to more than a slight imperfection, is of particular interest owing to the fact that Italians who are its subjects frequently present themselves before medical practitioners in the United States. *This dental abnormality is an acquired condition and is due to geological conditions and unsanitary surroundings. In Naples it has been attributed to the water supply, and since this has been changed the disease among infants has greatly diminished.*

“Denti di Chiaie” is really a collective name for various enamel defects. In Pozzuoli, a suburb of Naples, the inhabitants are distinguished from the people of the neighboring places by their black teeth (“denti neri”). *This defect is supposed to be caused by the noisome gases from volcanos. The theory most generally accepted in Italy is that these gases have a selective harmful effect upon enamel formation in early childhood, but that the growth of the other dental tissues is not interfered with. When the cause is active during the entire period of second dentition the whole tooth is deprived of enamel and becomes perfectly black. If the growing teeth are exposed for only a short time at the commencement of their formation, only the cutting edges of the upper incisors are affected, and the appearance when the teeth are matured is as if they had been browned by tobacco. The “denti scritti” (the teeth appearing as if written upon) constitute another form of Chiaie teeth. These cases are characterized by black markings crossing the incisor teeth in a horizontal direction.*

From *Public Health Reports* (1901):

November 1, 1901

ITALY

Denti di Chiaie (Chiaie teeth).

NAPLES, ITALY, October 7, 1901.

Sir: I have the honor to submit the following report: On the examination of certain Italian emigrants embarking at this port, one is struck with the frequency of a dental peculiarity common among the inhabitants of the Italian littoral and known as “denti di Chiaie,” or Chiaie teeth. This defect was first described by Prof. Stefano Chiaie, a celebrated Neapolitan, and bears his name.

The impairment of the teeth, often not amounting to more than a mere imperfection, is of particular interest, owing to the fact that Italians who are subjects of the defect frequently present themselves before the medical practitioner in the United States. The deterioration, however, is an acquired one, due to local geological conditions and so, because of altered hygienic surroundings, will not pass beyond the present generation of Italians in America. *Strong well-formed teeth not particularly prone to decay appear to be the rule among young Italians when they have not been subjected to the influence during infancy of the causes of Chiaie’s disease. The etiology seems to be connected with volcanic fumes or the emanations of subterranean fires, either fouling the atmosphere or forming a solution in drinking water. In Naples it is more often attributable to water than to the air, and since the Serino water, brought in conduits from a distant mountain height, has been in use and local wells condemned the incidence of the disease among infants has greatly diminished. Formerly nearly all children living in the section known as Santa Lucia, along the Riviera, and at Posillipo were affected.*

The people of Pozzuoli, a town of 16,000 inhabitants, situated 5 miles from Naples, are marked off from the people of neighboring places by their distinguishing characteristic of black teeth (*denti neri*), *apparently strong and serviceable*, but devoid of enamel and hideously dark. The environs of Pozzuoli are everywhere volcanic. Close at hand is the Solfatara, a half-extinct crater full of cracks from which gases are constantly issuing. Some of the inhabitants of Pozzuoli drink the water of springs, a water necessarily charged under pressure with volcanic fumes; all of them are constantly living in an atmosphere filled with noisome gases.

The theory most generally received in Italy is that these gases have a selectively hurtful effect on enamel formation in early childhood, but that the growth of the other dental tissues is not interfered with. When the cause is active during the entire period of second dentation, the whole tooth is bereft of enamel and becomes perfectly black. If the growing teeth are exposed for but a short time at the commencement of their formation, only the cutting edges of the upper incisors may be affected and the appearance, when the teeth are matured, is as if they had been browned by tobacco smoke in the same way that a meerschaum pipe is colored by smoking. Sometimes the teeth have the repulsive look of fever patients' teeth when smeared with sordes, except where covered by the half-parted lips.

Among the better class of Italians living inland, it is the custom to go to the seashore in summer. Naples has always been a popular resort, and as a result of the temporary exposure of children brought with their parents to Naples at the time when Serino water was not used, it is frequent to see among well-to-do people an otherwise handsome face marred by a line of fine, black markings crossing the incisor teeth in a horizontal direction. This fault of development is known among Neapolitans as "denti scritti" or writing on the teeth. The marking, when present on finely formed, white teeth, resembles the diminutive lettering which is sometimes done on seashells for purposes of ornamentation.

The different forms of deterioration which are grouped under the name of "denti di Chiaie" are thus seen to be quite unlike any other dental disease and not at all likely to be confounded with Hutchinson's teeth, mercurial teeth, carries [sic], or other maladies of the teeth.

Respectfully, J. M. EAGER,
Passed Assistant Surgeon, U. S. M. H. S.

What is remarkable about the two somewhat redundant Eager entries just given are the prescient comments about enamel mottling

that would be verified in the United States over the next thirty years. Several relevant sentences in the Eager excerpts given above are italicized for emphasis; for example, there is a recognition that enamel mottling is not genetic and is acquired from environmental sources, possibly from the water supply as in Naples. It is further noted that changing the water supply in Naples had also lessened the degree of enamel mottling in infants. As noted regularly in the United States, the defect is particularly endemic in certain volcanic areas and can be absent from neighboring districts (for example, it is endemic in Pozzuoli, a suburb of Naples, and absent in other nearby regions). One might remember that this area of Italy is the locale of Mt. Vesuvius and several destroyed cities, such as Pompeii, near the Bay of Naples.

These excerpts also indicate a knowledge that mottling occurs during the formation of enamel in early childhood. There is minor mottling (the “denti scritti”) if the exposure is for only a short time. There is also a hint about the possibly protective nature of the environment that in current times justifies communal fluoridation: “strong well-formed teeth not particularly prone to decay” and “apparently strong and serviceable.”

One of the more unique aspects of the Eager report is the observation that mottling decreases as a result of a change in the water supply. The case in point is Naples changing water sources to the Serino area. It is of some historical interest to note that water from the Serino region was also the basis of the Aqua Augusta (or Serino Aqueduct), one of the largest and most complex aqueduct systems of the Roman world (constructed from 33 to 12 B.C.). It ceased to function around 472 A.D as a result of volcanic eruptions at Mt.

Vesuvius.

Frederick McKay learned about the observations of J.M. Eager only as of 1912, although they appeared much earlier in *Dental Cosmos*. McKay had a chance to visit the Naples area described by Eager in 1927; he wrote an article about this visit in the *Journal of Dental Research* (1928) with the subtitle: “Report of an examination of an afflicted district in Italy.” The districts mentioned by Eager, such as Pozzuoli, had unfortunately (at least for McKay), changed their water supply and mottling no longer occurred. There was one town of Resina, however, that McKay did visit at some length that dramatically pointed to the water supply as the cause of enamel mottling and that a change in the water source was a means for its curtailment. We end this section on the beginnings of the fluoridation story by giving a rather extensive excerpt from this 1928 article that shows McKay’s now definitive stance that enamel mottling was from something in the water, and secondly that whatever it was, it may be particularly prominent in the presence of past volcanic activity.

In pursuing this investigation the writer confesses to an increased fascination in learning of, and particularly in examining, new affected districts or territories, doubtless because of the possibility that in one of them will be found some circumstance or condition that may prove to be the determining factor. At least each new place discovered might furnish evidence that would be confirmatory of that already gathered. All through the years since the writer read Eager’s report, he cherished the ambition to make a personal examination of the Italian district referred to in the above quotation. The opportunity to do so presented itself during August, 1927.

The one locality that is particularly mentioned in the quotation above, and in the related comments, is Pozzuoli, a suburb of Naples,

located just beyond the point of land that outlines the northern boundary of the Bay of Naples. This was the place which was expected to yield the most important data. The writer was informed, however, from the most reliable sources available, that whereas in former years this enamel lesion was freely produced there, as set forth in Dr. Eager's report, further occurrence had ceased and at present no cases were being produced. As an explanation it was stated that several years ago a change had been made in the water supply of that community and the water that had been in use at the time of Eager's report, which was derived from a sulphur spring or wells, had been discarded, a new supply having been installed for municipal use from an entirely different source. These statements could not at the time be verified, nor has it been possible since then to do so; but, if the circumstances as related are true, they constitute valuable evidence on the demonstrated water relationship with this enamel defect, and show also the specific effect of a change in the water supply. This evidence will become more valuable when it can be correlated with future results that are being awaited with intense interest, and which will be available in due time, following changes of the water supply for certain communities in our own country. (See the report on Oakley, Idaho, in *Dental Cosmos* for September, 1925.)

It was also stated to the writer that mottled enamel had formerly been produced in Naples, but that production had ceased during the past few years; and I understood that a change in the water supply had also been made there.

I was unable to gain more than hints of other communities in Italy where this lesion existed, and it is a matter of great regret that there were no means by which some of these additional places could be located and examined. In the neighboring city of Resina, however, it was my good fortune to come into direct contact with a district presenting one of the most interesting episodes among the many thus far recorded in this investigation of mottled enamel. A description somewhat in detail is therefore justified.

The city of Naples is located in that great curve of the western shore of Italy, known as the Bay of Naples, which is one of the beauty spots of the world. To the south a few miles and somewhat inland, further away from the shore, stands Vesuvius, with its perpetual column of smoke rising from its crater, in plain sight from Naples. In that immediate vicinity, the land has a gradual slope from the ocean shore up to the base of Vesuvius, and the whole sloping terrain is thickly dotted with small towns and villages. The largest of these is Resina, which is located practically at the foot of Vesuvius, where the tourist changes from the electric railway from Naples to the car that ascends to the crater. It was my good fortune to secure as my guide an employee of the Thos. N. Cook agency, who was not only a native of Resina, hence thoroughly familiar with the district and its people, but himself afflicted with a thoroughly typical case of mottled enamel one of those cases in which there was an extreme manifestation of the associated condition so often described as the "brown stain," except that the teeth were almost black.

These circumstances gave my guide a most personal interest in our examination of Resina, and before starting he imparted the astonishing information that within the city proper we would find the defective enamel only in adult individuals, and that the present generation of children would be found to be unaffected. Before we had gone very far I found that my guide was right, for he led me up alleys, into back yards and inner courts, and even into houses where he assumed all the prerogatives of a native son in personally opening the mouths and drawing back the lips, literally compelling the proletariat to show me their teeth, in the meantime keeping up a rapid-fire comment in Italian, *prestissimo*, to intimidate the unwilling. We were usually surrounded during these ceremonies by a motley group of women and children whose mouths were sympathetically half opened, wondering what it was all about. More than this, my guide in more than one instance had to assure the suspicious householders that I was not an agent of Mussolini, sent

to impose some new form of taxation, possibly upon those who were revelling in the luxury of mottled and stained teeth. But it was a fact that I was shown case after case of adult natives of this city who presented teeth typically marked, while we were not able to find one single native child who had anything but "normal" enamel. I was amazed at the acuteness of the observations of my guide prior to this tour of examination.

Upon inquiring into the water supply I received the further astonishing information that, until a few years ago, when water from the slopes of the hills adjacent to Vesuvius had been piped into the city, these adult people had been dependent upon water from wells located in the court yards and used by several families. I saw some of these abandoned wells, which were of an inside diameter of about seven or eight feet, and an average depth of about fifty feet. Water was of course still standing in them, but that they were not being used was evidenced by the accumulation of rubbish and debris. The municipal installation was not like our own, although I saw several houses in which there were pipes and faucets, but a large proportion of the population got their household supply by going with pails and pitchers to open spigots in the streets. The important fact, then, is the observation that these adult native cases grew their enamel while the well-water was being used, but the present generation, which is free from the disorder, grew their enamel under the piped-in water. The significance of this observation must be evident to those who compare this finding with the many similar instances described in our previous articles on this subject. In order to have a complete understanding of the conditions of life in a community like Resina, it should be pointed out that often, if not as a rule, generations of these families, from birth, live in the same dwelling houses. Owing to the most stringent economic conditions, their migrations are exceedingly limited, and they seldom travel far afield. Therefore, such an influence as this water relation is practically constant. Their habits of life, including diet, also remain practically unchanged from one generation to another.

My guide understood, then, that I wanted to see some children who were afflicted with this enamel defect, and so we took our way into the outlying district of the city. The streets of Resina are extremely narrow and enclosed by high walls of stone. The footway was inches deep with dust, ground to an impalpable fineness. There were no shade trees, and an August sun was in the skies. It had not rained for about five or six months, and the heat was an inferno such as I have seldom experienced.

In this outlying district our method of examination was a house to house canvas, the families being personally known to my guide. These people were engaged in farming small plots of land. Because of conditions similar to those obtaining within the city of Resina, as described above, not only had the children been born and reared on these small plots where they are now living, but in the immediate vicinity the parents also. Precisely the same character of data was found in going from one house to another. Without exception these children and their parents presented illustrations of this defect of the enamel, including the brown discoloration, which were as typical as any recorded throughout the progress of this investigation. It is of additional interest to point out that the appearance of the enamel here follows every phase and characteristic of the lesion existing in all of the afflicted districts heretofore described and illustrated.

THE STORY CONTINUES —

By the late 1920s, the protective nature of enamel mottling against dental caries was established, although the intervening reason of having fluoride in the water was as yet unknown. Or, stated otherwise, we have McKay's second major abductive conjecture of his career: whatever is in the water that produces enamel mottling is simultaneously protective against the development of dental caries. As early as the Black/McKay papers from 1916, mottled enamel was observed to be no more prone to dental caries than normal enamel. But it was a 1929 paper by McKay in *The Dental Cosmos* that this relationship was stated in a more positive way, with the article's title being a good introductory summary: "The Establishment of a Definite Relation between Enamel that is Defective in Its Structure, as Mottled Enamel, and the Liability to Decay." Several excerpts from this paper are given below that reflect McKay's astonishment about the actual protective effects of enamel mottling:

At the beginning of this investigation mottled enamel was thought to be a condition which bore little relation to practical dentistry, inasmuch as the afflicted districts were of small population, usually remotely located, and also because not more than a few practitioners elsewhere would, in a lifetime, ever observe an actual case.

As the investigation has proceeded, it has been found, with astonishment, that large populations in various districts of our own country are subject to this disfigurement, and that this enamel dystrophy has a distribution throughout the world that was not suspected in the beginning. Concerning this latter only a little is as yet known.

It is my purpose at the present time to consider the relation which this enamel defect bears to the liability to decay.

The hypothesis set forth in the many writings, namely, that de-

cay is superinduced chiefly because of the enamel being “defective” or “poorly calcified,” must now be made to face the evidence presented by the facts in the case. We have reached a point where it is no longer necessary to hold to this idea as an explanation of the cause of decay. It may have seemed necessary in the past in order to rationalize our experiences, but its continuance only obscures a clear comprehension of our present wider knowledge, and we cannot afford to hold it at such a price.

As has been stated in previous papers, mottled enamel presents a condition in which there has been almost a complete failure of actual calcification, constituting the most poorly constructed enamel of which there is any record in the literature of dentistry. Not only is the cementing substance completely lacking throughout much of the enamel structure in some of the more pronounced specimens, but the rods themselves are grossly defective. The extent of the damage has been amply dealt with in previous writings.

According to the accepted standards of the hypothesis stated in a previous paragraph, such enamel would be completely incapable of withstanding the attacking forces of caries, and must of necessity fall an easy prey.

Would not such enamel be incapable of exerting the alleged “resistance to decay” which was discussed at some length in a previous paper published in the DENTAL COSMOS for July 1929, being deprived thus of all but a merest semblance to normality?

What are the facts? Overwhelmingly, that this defective enamel exhibits no greater liability to decay than does normal enamel. This revelation came in so gradual a manner that it was only recently its full significance was apparent.

The universal testimony of all who are familiar with conditions in any of the various endemic districts has been to the effect that such teeth are not to any greater extent liable to decay.

In my own experience the evidence was nowhere more completely convincing than in the afflicted community of Bauxite, Arkansas.

Although the damage inflicted by the defective calcification of

the enamel in that community was more severe than in any other locality previously examined, both as to the percentage of the population afflicted and in the extent of the damage to the teeth, the prevalence of decay was not proportional to the occurrence of the enamel lesion.

It is a further significant fact that more extensive carious involvement was observed in the neighboring community, Benton, only four miles away, in which there was not a trace of mottled enamel in any native individual.

...

My own conviction, prior to these examinations and based on the observations of the past several years, was that mottled enamel was not more liable to decay than was normal enamel, but to find it consistently less liable in these communities was a complete surprise.

If this same consistency should be found generally established throughout other endemic districts, a fact would thereby have been presented that is of profound importance to the science of dentistry, particularly as it relates to the conditions which contribute to decay and its prevention.

Soon after fluoride was shown to be the culprit behind the mottling of enamel, the further study of the fluoride–enamel mottling–dental caries nexus passed to H. Trendley Dean (1893–1962). In 1931, Dean became head of the newly-formed Dental Hygiene Unit of the National Institute of Health (NIH). After first replacing the term “mottled enamel” for the more general one of “fluorosis,” Dean began a systematic epidemiological study of fluorosis in the United States, and of the correlation between the levels of fluoride in communal water supplies and the severity of fluorosis in those areas served by the respective water sources.

Before the main question of ascertaining how high fluoride levels

could be before fluorosis occurred, an initial task that needed solution was the construction of an accurate and easily implemented test for the presence and amount of fluoride in a water sample. A senior chemist at NIH, Elias Elvove, produced an appropriate instrument having an accuracy of plus or minus 0.1 ppm. Elvove also became Dean's co-author on a series of papers in the 1930s and 40s resulting from what was referred to as "shoe-leather" epidemiology; this search was characterized by visits to many areas in the country along with a concomitant dental examination of groups of children typically aged from twelve to fourteen. Although Dean initially set out to study the question of harm that too much fluoride could cause, by the late 1930s the emphasis had changed to the prophylactic properties of having a small amount of fluoride present in a communal water supply.

A comprehensive summary article entitled: "Domestic Water and Dental Caries," appeared in *Public Health Reports* (August 7, 1942), authored by H. Trendley Dean, Francis A. Arnold, Jr. (another dental surgeon assigned to the project), and Elias Elvove. It is commonly referred to as the "21 cities study," and represents the culmination of a decade of work on the fluorosis–dental caries–fluoride nexus. The summary section of this paper follows; note in particular that the low threshold of 1.0 ppm is generally high enough for good caries protection but without the presence of any serious fluorosis – Dean referred to this level of 1.0 ppm as "the minimal level of dental fluorosis."

1. A study of the intensity of dental caries attack, as evidenced by the observed dental caries experience, disclosed striking differences among children of different cities. This study embraced 7,257 white urban school children, aged 12 to 14 years, of 21 cities; in the main the children were apparently of largely comparable circum-

stances and the groups examined were relatively equitable respecting sex ratio. The groups studied were limited to those children continuously exposed throughout life to the variable under investigation (the common water supply). Clinical examinations in all 21 cities were made by the same two dental officers and in each city an equal number of children were examined by each examiner. It seems unlikely that such marked differences in the prevalence of dental caries can be explained on the basis of the hardness of the domestic water, the hours of sunshine, or gross dissimilarities in diet (water excluded).

2. A general inverse correlation between the fluoride concentrations of the public water supplies in the 21 cities studied and the amount of dental caries was observed. Differences in dental caries experience rates of as much as 2 and 3 times the observed minimal were not unusual; the highest rate ... at Michigan City (Ind.) was 4.4 times that observed in the city with the lowest rate ... at Galesburg (Ill.). Strikingly low dental caries prevalence was found associated with the continuous use of domestic waters whose fluoride (F) content was as low as about 1 part per million, a concentration which under the conditions prevailing in the localities studied produced only sporadic instances of the mildest forms of dental fluorosis of no practical esthetic significance.

3. As in previous studies, marked differences were observed with respect to: (a) The amount of dental caries experience in the proximal surfaces of the four superior permanent incisors, and (b) the first permanent molar mortality rates. Of the 4,425 children of the 13 cities whose caries experience is reported in detail in this report, the 2,859 children living in communities whose public water supply contained less than 0.5 ppm of fluoride (F) showed about 19 times as much proximal surface caries experience in the four superior permanent incisors as was observed in the 1,566 children living in cities where the common water supplies contained from 0.6 to 2.6 ppm of fluoride (F). In these same two groups of children, the first permanent molar mortality rate for those living where the wa-

ter supply contained less than 0.5 ppm of fluoride (F) was about 4 times as high as that observed in the children using a domestic water containing more than 0.5 ppm of fluoride (F) (66.0 and 15.6 per 100 children examined, respectively). Inasmuch as the group with the higher first permanent molar mortality rate showed 38 percent of its total first permanent molar caries experience with fillings as opposed to only 26 percent in the group characterized by the lower mortality rate, there would seem justification in assuming that such differences in first permanent molar mortality rates are influenced to a considerable degree by a variation in either the intensity of dental caries attack, and/or the resistance of the teeth to caries attack.

So, in summary one might say that although Dean set out to study the harm that too much fluoride could do, he actually ended up showing the good that a little fluoride could do.

In the 1930s and continuing into the early 1940s, a number of naturalistic situations were identified that further added to the evidence of a strong causal connection between the presence of water fluoride and reduced dental caries in both children and adults. For instance, immediately after the water supplies of Oakley, Idaho and Bauxite, Arkansas were changed to avoid severe enamel mottling (or fluorosis), the experience of dental caries increased markedly among those residents now growing up on the “new” water. In short, the increase in caries was the cost incurred for the absence of fluorosis. Three additional naturalistic situations are discussed below that also point to strong causal connections between fluoride and reduced dental caries experience.

In the early 1920s, a dentist from Essex County in England, Norman Ainsworth, carried out a study on behalf of the Medical Research Council which was published in 1925. The study involved the dental

examinations of 4258 children from 36 schools in England and Wales. Among the schools visited, two were from Ainsworth's own town of Maldon (Essex) with an enrollment of 202 children. Over all children examined, the percentage of permanent teeth with caries was 13.1%; but for the Maldon children alone, the percentage was 7.9%. Among the 134 lifelong Maldon children, 125 showed significant mottling. This study was among the first that showed an actual reduction in caries experience in the presence of enamel mottling, and not merely that mottling did not seem to increase caries. Ainsworth became aware soon after it was published of Churchill's discovery of fluoride in areas of endemic mottling, and proceeded to test for fluoride in the endemic mottling area around Maldon; readings of 4.5 to 5.5 ppm were obtained. A nearby town of Witham with no endemic mottling tested at 0.5 ppm for fluoride.

Two further naturalistic situations that involved the relation between dental caries and fluoride occurred as a result of World War II. The first was discussed extensively by Henry Klein in the unfortunate context of Japanese-American internment. The second concerned English children evacuated to the Lake District from industrial towns subject to German bombardment. We begin with the United States and Japanese-American internment.

Late in 1942, 316 children of Japanese ancestry were transferred along with their parents from Los Angeles to two War Relocation Centers in California and Arizona. As it so happened, the center in California had, in effect, fluoride-free water; the Arizona center, on the other hand, had a rather high fluoride content of 3.0 ppm. After two years of residence and considering only the 8 to 10 year-old children, the occurrence of new caries was reduced by 60%; also,

it was evident that the most recently erupted teeth were the most protected. So, even though tooth decay was lessened the most upon exposure to fluoride water past the date of birth but before tooth eruption, such a reduction also occurred in permanent teeth that erupted during the time of exposure.

To indicate more clearly this story of caries experience among these relocated Japanese-American children, the introduction and conclusion of an article by Henry Klein is included below. It appeared in *Public Health Reports* (December 7, 1945) with the title: “Dental Caries Experience in Relocated Children Exposed to Water Containing Fluorine — Incidence of new caries after 2 years of exposure among previously caries-free permanent teeth.”

In the course of systematic dental examination of persons of Japanese ancestry residing in War Relocation Authority centers, two groups of children at two different centers were examined in the summer of 1943 and again in the summer of 1945. Early in 1942 both groups, because of their Japanese ancestry, had been transferred with their parents from homes in Los Angeles and environs to an assembly center near Los Angeles. In the autumn of 1942 they were again transferred, 120 to a center in California and 196 to Arizona.

The children relocated to the California center consumed fluoride-free water originating from melted snows coming off a precipitous mountain rising to a height of more than 14,000 feet, less than 20 miles from the residence area. Analysis of this water revealed a fluoride content of 0.1 ppm, a value within the error of measurement. The children relocated to the Arizona center consumed water originating from two deep wells drilled through the desert floor to a depth of approximately 400 feet. This water contained fluoride to the extent of 3 ppm. Water from the central source was piped to each family apartment in both centers.

Because of the relatively high fluorine content of the water in the Arizona center, an attempt was made by the Relocation Authority to remove the fluorides. Bone-meal filters were installed only at selected water outlets to which the population had to travel to obtain fluoride-free drinking water. After a trial of several months, treatment of the water in this manner was discontinued. Bottled fluoride-free waters were shipped into the center and sold to residents who reserved such water chiefly for the preparation of dietary formulae for infants. The children of school age obtained their drinking water from the nearest tap, which provided water containing fluorine (except during the 3-month period mentioned above, when fluoride-free water could be obtained, if so desired, at several selected outlets).

In the early summer of 1943, the school children were examined with the aid of dental mirrors and explorers; the same children were reexamined 2 years later in the summer of 1945. All examinations were recorded by the methods previously utilized in the Hagerstown Dental Studies. During the 2-year interval, the children were restricted to their respective centers, since movement in and out was controlled by military authority. Their diets were quite similar and adequate.

Analysis of the dental findings obtained in 1943 and in 1945 reveals that a fluoride content of 3 ppm in the drinking water is associated with a marked reduction in new caries in teeth present in the mouth and free of caries at the beginning of exposure.

...

These findings lead to the conclusion that, among young children (ages 8 to 10 years) transferred to an area where the drinking water contained 3 ppm of fluoride, the incidence of new caries experience in previously non-carious erupted teeth was reduced approximately 60 percent below that which would be expected on the basis of the incidence observed in the control group. The data are sufficient to indicate that exposure of the erupted permanent teeth of younger children to fluoride waters provides a larger measure of protection

against caries than does the same exposure of the erupted teeth of older children. It follows therefore that, among teeth present in the mouth at the beginning of exposure to fluorine, those most recently erupted were those most protected against caries attack.

A second story that resulted from the disruptions caused by World War II, originated in England. Because of the constant threat of German bombardment in industrial areas, children were regularly evacuated away from industrialized regions to places not considered military targets. One such relocation involved children coming into the Lake District from South Shields, an industrial town on the Tyne River in northeastern England. A senior school dentist for Westmoreland County noted that evacuees had much better teeth than did local children. This observation prompted a dentist from the Ministry for Education, Robert Weaver, to have the South Shields water tested for fluoride. It measured at 1.4 ppm; on the other side of the Tyne River in North Shields, the water tested at a low 0.25 ppm.

In 1943 Weaver examined 1000 children on either side of the Tyne — 500 5 year-olds and 500 12 year-olds. Lower decay rates were found in children from South Shields in both the permanent and deciduous teeth. Caries in deciduous teeth in the 5 year-olds was 60% of the figure for North Shields; in 12 year-olds and for permanent teeth, the figure was 56% of that for North Shields. This was among the first studies to show a caries reduction in deciduous teeth attributable to water fluoride.

There are more instances that could be presented where natural fluoridation was associated with a reduced caries experience for residents relying on that fluoridated water source. Many of these are

discussed in the comprehensive text by Frank McClure, *Water Fluoridation: The Search and the Victory* (1970); there are none that are more serendipitously interesting, however, than those already presented. So, it may be time that our story moves on to instances where communities agreed to artificially fluorinate their common water supply, typically to a 1.0 ppm level that was supposedly the point where caries reduction could be achieved without any concomitant severe fluorosis.

The first experimental study of the effects of adding fluoride to a communal water supply was guided by none other than H. Trendly Dean. The two Michigan cities that agreed to be part of this first study were Grand Rapids and Muskegon, with Grand Rapids having its water artificially fluoridated to 1.0 ppm starting as of January 25, 1945. The water of Muskegon was to remain fluoride-free and thus would act as a control. Dental examinations were begun in September of 1944 for children aged 4 to 16 who were continuous residents from birth of either Grand Rapids or Muskegon; 19,680 examinations were done in Grand Rapids and 4,291 in Muskegon. The city of Aurora, Illinois was considered another “control city” but one with naturally fluoridated water at 1.4 ppm; 5,116 children of continuous residence in Aurora were also given dental examinations starting in the Fall of 1944.

There is an interesting aside about the onset of water fluoridation in Grand Rapids that mirrors some of the opposition to fluoridation that exists to the present. Fluoridation in Grand Rapids was supposed to start on January 1, 1945, which was a date heavily reported in the local news media. Immediately after this announced beginning there were numerous complaints of physical ailments that

people attributed to the onset of fluoridation. As it so happened and because of some mechanical issues, the actual fluoridation of the Grand Rapids water supply did not begin until January 25, 1945, a date beyond when the reports of these physical ailments were made. This is yet another example of abductive reasoning gone awry, or at least how expectancies may influence one's experiences.

The first results of the Grand Rapids-Muskegon study after $6\frac{1}{2}$ years were formally published in *Public Health Reports* (February, 1953) by Francis A. Arnold, H. Trendley Dean, and John W. Knutson, with the title: "Effect of Fluoridated Public Water Supplies on Dental Caries Prevalence." The summary section of this seminal article is given below; note that on the basis of the positive results for Grand Rapids that were known prior to this publication date of 1953, Muskegon decided to fluoridate its own water supply starting in July of 1951.

The methodology and results after 7 years of the Grand Rapids-Muskegon study have been described. The 1951 results on continuous resident children after $6\frac{1}{2}$ years of fluoridation of the Grand Rapids water supply indicate:

1. There has been a reduction in dental caries rates in permanent teeth of Grand Rapids children ranging from 66.6 percent in 6-year-old children to 18.1 percent in the 16-year age group. Similar results have been obtained regarding the deciduous teeth.

2. Similar reductions have not been observed in Muskegon where the water supply remained "fluoride-free" (less than 0.2 ppm F) until the last 3 months of this study period.

3. This change in dental caries rates at Grand Rapids was also reflected in observations based on objective assessment, that is, a reduction in the number of missing teeth.

4. A comparison of the 1951 caries rates in Grand Rapids with those of Aurora, Illinois, shows that insofar as can be determined to

date the use of a fluoridated water gives the same beneficial effects as does the use of a natural fluoride water of similar concentration.

Besides this 1953 publication reporting on the Grand Rapids-Muskegon study after $6\frac{1}{2}$ years, two more were done after 10 and 15 years; the 10-year discussion and summary given below appeared in 1956:

From the results obtained in Grand Rapids after 10 years of water fluoridation, it is quite clear that this procedure is remarkably effective in reducing the incidence of dental caries. These observations are in accord with the results of similar studies conducted under separate auspices ... The scientific evidence is conclusive, therefore, that water fluoridation is an effective public health procedure for producing a substantial reduction in the incidence of dental caries.

According to this study, the beneficial effects of fluoridated water are not confined to persons drinking the water since birth. The results suggest that some benefit was obtained by persons whose teeth had already formed or erupted when they started drinking fluoridated water. The effects on the teeth of adults in these cities have not as yet been ascertained. However, the fact that a reduction in caries was observed for teeth which had already been calcified when fluoridation was started indicates that some beneficial effect may be gained by older age groups.

The possibility of an increase in dental fluorosis in a community after fluoridation has received considerable discussion. After 10 years of fluoridation in Grand Rapids, the percentage of children classed as having fluorosis has increased, but, as anticipated, this increase is confined to the milder forms. As pointed out previously ... , the signs of the milder forms of fluorosis caused by ingestion of water containing 1 ppm fluoride as a rule do not appear on the anterior teeth. It is the plan of this study to continue the observations to evaluate this factor fully. Thus far, however, the ingestion

of the Grand Rapids water supply has not produced any undesirable cosmetic effect in the form of objectionable dental fluorosis on the anterior teeth.

...

The results of the Grand Rapids-Muskegon study after 10 years of observation indicate that the adjustment of the fluoride content of a communal water to an optimal level (approximately 1 ppm fluoride) will produce the following effects:

1. A striking reduction in the prevalence of dental caries in the deciduous teeth. At the peak of prevalence, namely 6 years of age, the caries rate for the deciduous teeth was reduced by about 54 percent.

2. A marked reduction in the prevalence of dental caries in the permanent teeth. In children born since fluoridation was put into effect, the caries rate for the permanent teeth was reduced on the average by about 60 percent.

3. Some benefit among persons whose teeth having already formed or erupted when fluoridation is begun.

4. No undesirable cosmetic effect from dental fluorosis.

After fifteen years of water fluoridation in Grand Rapids, dental caries had been reduced by 50 to 63 percent in children aged 12 to 14, and by 48 to 50 percent in children aged 15 or 16. The report published in 1963 included the following summary statement, with obvious implications on the restriction of sugar for children and how that relates to the prevalence of dental caries.

No such dramatic and persistent inhibition of caries in large population groups had even been demonstrated by any other means than fluoridation of a domestic water supply. While there were marked decreases in caries attack rates of European children during World War II, these were associated with restriction of sugar.

A number of other studies were initiated in the 1940s and 1950s

that involved the pairing of an experimental (E) city with a control city (C): Brantford, Ontario (E) and Sarnia, Ontario (C); Newburgh, New York (E) and Kingston, New York (C); Evanston, Illinois (E) and Oak Park, Illinois (C). These studies all showed a caries reduction of some 50 to 70 percent among children subjected to the fluoridated water since birth. These studies all used sequential cross-sectional surveys implying that although age-group effects could be obtained, because individual children were not explicitly followed longitudinally, the specific reasons for a caries reduction in an individual could not be ascertained. A study started in the Netherlands in 1953 (Tiel – Culemborg) was done longitudinally so the effects on specific individuals could be studied. The conclusion was that caries inhibition is not uniform but is most effective on smooth surfaces and less so in pit and fissure caries.

THE BATTLES BEGIN —

Based on the fluoridation trials begun in the 1940s as well as on all of the non-experimental evidence amassed in the first half of the twentieth century, many communities in the United States and elsewhere began to fluoridate their communal water supplies in the 1950s and 1960s. Many if not most of these implementations were accompanied by hugely contentious debates as to the wisdom of adding fluoride to a community's water. As documented extensively by Donald McNeil in his *The Fight for Fluoridation* (1957), many of these early fights occurred in Wisconsin, such as in the run-up to Madison beginning communal fluoridation as of March 1950, even before many of the fluoridation trial results were completely known.

To illustrate how these debates were phrased, we begin by giving three items relevant to the fluoridation of New York City water. The first is part of an obituary for David Ast, one of the fiercest advocates for communal water fluoridation. Ast led the fluoridation trials for Newburgh and Kingston, New York. The second item is from the *New York Times* on November 18, 1963, and written by the well-known science writer, Walter Sullivan. This article concerns the contentious debate then underway to fluoridate the water for New York City. The third and last item is also from the *New York Times* (February 23, 2015); it takes a 50-year backward look at the controversy that raged in the early 1960s regarding New York City water fluoridation.

Dr. David B. Ast, 104, Pioneer in Efforts to Fluoridate Water,
Dies

By JEREMY PEARCE

February 23, 2007

Dr. David B. Ast, a dentist and public health official who led an effort to begin fluoridating the water supply in New York State in the 1940s and helped prove its safety and effectiveness in preventing tooth decay, died on Feb. 3 in Laguna Hills, Calif. He was 104.

The cause was heart failure, his family said.

In 1944, Dr. Ast began a 10-year study of fluoridation that became evidence of the benefits of treating public water and made a strong case for wider use. He selected two towns of comparable size along the Hudson River, Newburgh and Kingston, and compared the health and dental records of their residents.

During the study, Newburgh's water was treated with fluoride compounds; Kingston's water did not have fluoride. At the time, opponents of fluoridation in New York and elsewhere argued that the compounds could pose unknown health risks and that adding them could even be unconstitutional.

Yet Dr. Ast and his colleagues at the state's Bureau of Dental Health reported significant results. Children 6 to 9 years old in Newburgh had a 60 percent reduction in numbers of cavities, a reduction that approached 70 percent by the time they reached the 12-to-14 bracket. As important, comparisons of cases of cancers, birth defects, heart and kidney disease showed no significant differences between the two towns.

While many other communities across the United States were already fluoridating their water, the success in Newburgh was subsequently used as a landmark case study for other municipalities in New York State, and Dr. Ast became a prominent advocate for treating New York City's water supply, which did not start until 1965. In the 1950s, Dr. Ast and others repeated the experiment in Mineola, on Long Island, and confirmed their positive results.

Dr. Arthur Bushel, a dentist and former deputy commissioner of the New York City health department, credited Dr. Ast with planning and guiding the Newburgh-Kingston study and "proving that you could do fluoridation dependably and safely."

Dr. Bushel, who was president of the American Board of Dental

Public Health and who also worked on the study, added, “The issue led to interesting battles — to quite a furor, actually — but the study did much to put them to rest.”

David Bernard Ast was born in New York City. He received his dental degree from New York University and a master’s degree in public health from the University of Michigan.

He practiced dentistry before joining New York State’s Bureau of Dental Health in 1938. He served as the bureau’s director before becoming an assistant commissioner of the State Department of Health.

FLUORIDE BATTLE TO RESUME TODAY; APPROVAL LIKELY

Public Hearing to Be Held on Plan Backed by Wagner to Reduce
Tooth Decay

FOES SEEK REFERENDUM

Proponents Ask Funds for 9 Plants to Put Compound into Drink-
ing Water

By WALTER SULLIVAN

November 18, 1963

The long-delayed public hearing on the controversial plan to fluoridate New York City’s drinking water will be held today, and political observers believe that this time the measure will go through.

The hearing in the Board of Estimate chamber is expected to be stormy, like its predecessor. But observers note that after a decade of bitter debate, “this time there is an added element of strength on the side of those favoring fluoridation.” The new factor is the invigorated political strength of Mayor Wagner, a backer of fluoridation. His success in consolidating his political power is regarded as giving him sufficient influence in the City Council and Board of Estimate to have his way.

Better Teeth the Aim

The Mayor favors fluoridation — the introduction of a fluoride, a compound of fluorine and another element — as a means of reducing

tooth decay in those whose teeth are still forming. Once such teeth have matured, fluoridation advocates contend, their resistance to decay will endure a lifetime.

Although opponents of fluoridation have sought to delay action by calling for a referendum, the Mayor can block any such move.

Today's hearing at City Hall by the Board of Estimate and the City Council's Finance Committee, starting at 10 A.M., will be on a proposal to amend the expense budget to appropriate \$565,000 to construct nine fluoridation plants and \$798,000 for their initial operation and maintenance.

As far back as 1952, the Board of Health first recommended fluoridation. The Board of Estimate held a hearing March 6, 1957, that took 14 hours of testimony with 34 speakers in favor and 54 against.

Votes in Favor Rise

The program was not pressed because Mayor Wagner could count only eight votes in its favor — his own four and the four of Abe Stark, then the Council President — while against it were 12 votes, held by officials no longer in office.

Currently, the Mayor is believed to have the support of Council President Paul R. Serevane, who is in Palm Beach, Fla., recuperating from an operation, making eight citywide votes again, while Mr. Stark holds two votes now as Borough President of Brooklyn.

Borough President Edward R. Dudley of Manhattan, who also has two votes, has been considered in favor of fluoridation, but he said on a WABC Press Conference program yesterday that he had an open mind. There are 22 votes on the Board of Estimate. Now it appears not only that the Mayor has gained in political strength but also that the climate of opinion has softened. In recent weeks advertisements in the local press, urging opposition to the measure, prompted City Hall to install an extra telephone operation to handle the protest calls. On Friday it was reported that only one such call had been received.

In addition, City hall had received 418 printed postcards and

206 letters in opposition, as against 224 letters in support of fluoridation. The smallness of these numbers was thought to indicate less excitement over the question than existed six years ago.

In the past, the controversy has been so emotional that it has attracted the interest of a number of sociologists. Sober scientific debate has often been beclouded by name-calling. Such expressions as “crack-pots,” “unadulterated scientific hogwash,” and “red plot,” are seen in the propaganda issued by certain elements on both sides.

When the hearing begins many of the arguments will echo those at the earlier hearing. However, supporters of fluoridation will have to reply to several recent reports that have been seized upon by the opposition.

The most recent of these is a letter, published in the *British Medical Journal* on Oct. 26, stating that sodium fluoride seems to inhibit the growth of human cancer cells and certain mouse cells. The cells, in both both cases, were being grown in flasks. Some persons have taken this to mean that fluorides inhibit cell growth in general.

Rebuttal Expected

Public health authorities are expected to come to the hearing armed with a letter from Sir George E. Godber, Chief Medical Officer of the British Ministry of Health. He has questioned various aspects of the finding reported in the *Medical Journal* and argues that it is inapplicable to the fluoridation question.

Public health specialists in this country and in a number of countries abroad believe there is no evidence of any ill effects from fluoridation when done properly. The worst that happens, when fluoride levels are too high, they say, is a discoloration of the teeth.

Only when fluoride levels are well above those recommended is the discoloration said to be discernible, except by a specialist. Some of those who have grown up in areas naturally rich in fluorides have badly discolored teeth, but they do not appear to have suffered any other ill effects. Like those exposed to lesser levels, they have much lower rates of tooth decay than those in fluoride-deficient areas.

This evidence and that of various other studies has produced overwhelming support for fluoridation by medical organizations. Those who have come out strongly in favor of it include the World Health Organization, the United States Public Health Service, the American Medical Association and the American Dental Association.

Opposition Continues

Yet there continues to be opposition, not only among the less well-informed who believe drinking water can be kept “pure” but also among a certain number of scientists and physicians motivated by caution.

They are mindful of the consequences of past impetuosity. For example, it was once the practice, when a child had an enlarged thymus, to shrink the thymus by means of X-rays. The function of that gland was unknown at the time, but it now appears to help the body develop immunity. Some of those thus treated with X-rays are now in constant peril of infection.

The improper screening of thalidomide, a tranquilizer that produced deformed babies, is another memory that haunts the medical profession. The spread of man-made chemicals through our environment, with subtle consequences that may not become evident for many years, is yet another worry. For example, the insecticide, DDT, is now being found in mid-ocean fishes and arctic plants.

One of the more distinguished dissenters is Dr. Ludwik Gross of the Veterans Hospital in the Bronx. Last year he was given a \$10,000 prize by the United Nations for his contributions to cancer research.

An ‘Insidious Poison’

In a series of letters to this newspaper he has termed fluorine “an insidious poison, harmful, toxic and cumulative in its effect, even when ingested in minimal amounts.” It is only partially discharged from the body through the kidneys, he said.

Although many opponents of fluoridation demand the retention of “pure” drinking water, all water supplies actually contain various

substances in small quantities, some of which are essential to health.

The fluoride level that health authorities are recommending is roughly one part to one million parts of water. At that level, proponents believe they get optimum results without objectionable mottling.

Of the 16,885 water systems in the United States, according to the Public Health Services, 1,934 have natural fluoride content considered sufficient for healthy teeth. These systems service some 7,261,000 persons.

As of last January 3, 284 other systems, servicing 51,306,700 citizens, added fluorides to augment the natural fluoridation. And 1,350 other systems serving 44,045,400 people, depended entirely on artificial fluoridation. Of 103 systems that had begun fluoridation and suspended it, 20 had reinstated the practice.

A few days ago Dr. Linus C. Pauling suggested that the recommended fluoride level may have been that of the water drunk by man through his period of evolution. This, he said, may be why the body chemistry responds so well to it.

Dr. Pauling has won two Nobel Prizes. The first, in 1954, was for his work in chemistry. The second, this year, honored his efforts toward a cessation of nuclear weapons testing. It grew largely from his warnings as to the possible effects of even small radiation doses from fallout, on human bodies and progeny.

Not Like Radiation

In a telephone interview he said that low fluoride dosages did not act like small doses of radiation. It is feared that even the smallest exposure to radiation may affect at least some members of the population, he said, whereas with the fluorides, doses below a certain level seems harmless to everyone. Dr. Pauling is strongly in favor of fluoridation.

His argument as to the "natural" fluoride content of drinking water was based on the assumption that primitive man drank largely from springs and other sources rich in mineral content. Today the great reservoirs supplying many cities, such as those of New York,

are low in such minerals. That is, the water is very “soft.”

The discovery of the beneficial effects of fluorides grew out of the almost lifelong efforts of Dr. Frederick S. McKay to track down the cause of tooth-mottling. In 1901, as a newly-graduated dentist, he moved to Colorado Springs, where he soon noticed the widespread staining of teeth. In a survey of 2,945 schoolchildren he found that the teeth of 87.5 per cent of those native to the area were stained.

Aluminum Studied

In the years that followed, such staining was found in many communities, both in this country and abroad. The stains were found only in those who had lived in the affected areas during their earliest years, when the enamel of their teeth was forming.

It was also noted that residents of these areas had remarkably few cavities.

Although the water supplies were suspected, nothing unusual was found in them by means of the analytic techniques then in use. Even in areas of heaviest staining the water seemed clear, pure and odorless. It was not until 1928 that the answer came out of one of the numerous communities studied by Dr. McKay.

This was the Arkansas town of Bauxite, named for the aluminum ore that was its livelihood. It was beset with tooth-staining and this troubled the Aluminum Company of America. There were whispers that aluminum cooking utensils made the food unhealthy. It was reportedly feared that news of mysterious tooth-staining at Bauxite would lend credence to this rumor.

Hence a careful spectrographic analysis of trace elements in the Bauxite water was carried out, showing it to contain fluorine at the very high rate of almost 14 parts per million.

The next step was to determine the minimum desirable fluoride level. This was undertaken in 1931 by Dr. H. Trendley Dean on behalf of the Public Health Service. His approach was to examine residents of American communities whose water contained a wide variety of fluoride levels.

In South Dakota alone he studied 40 areas rich in fluoride levels.

In Illinois he found that the children of Quincy, with little fluoride, had three times as many cavities as those in Galesburg, with a level of 1.8 parts per million. He concluded that the ideal was a fluoride content of roughly one part per million.

This led to the proposal that fluoride content be adjusted to this level in all water supplies. This, it was thought, would strengthen tooth enamel against decay without producing observable stains.

As a test it was decided to fluoridate the water of Grand Rapids, Mich., and compare the dental history of almost 20,000 children there with that of children in nearby Muskegon.

Thus, on Jan. 25, 1945, in the Grand Rapids experiment, sodium fluoride was added artificially to a water supply for the first time. On May 2, 1945, fluoridation began in Newburgh, N.Y., with nearby Kingston as the standard of comparison.

Enthusiasts Impatient

Both experiments were designed to continue for 10 to 15 years, but early results made fluoridation enthusiasts impatient, and by 1951 the Public Health Service was recommending fluoridation wherever indicated. Muskegon decided against waiting out the control period and fluoridated its own water.

The 10-year study brought reports indicating an over-all reduction in tooth decay approximating 60 per cent among children in both Newburgh and Grand Rapids. The New York State Health Department reported in December 1955 that Newburgh children aged 6 to 9 had 58 per cent less tooth decay than the Kingston children; Newburgh youngsters aged 10 to 12 had 52 per cent less decay, those 13 to 14 had 48 per cent less decay and those 16 years old had 41 per cent less.

By then, 1,225 communities were fluoridating water for a population of more than 24 million. A report on the 15th year of the Grand Rapids study, published last December by Dr. R. A. Arnold Jr., director of the National Institute of Dental Research, and associates, said that children then 12, 13, or 14 years old had, respectively, 57, 63 and 51 per cent less tooth decay than children

observed in Grand Rapids in 1944-45; children aged 15 and 16 had 50 per cent less.

Urged Here in 1952

In New York, as early as 1952, the Mayor's Committee on Management and the Board of Health recommended fluoridation. Across the country there was talk of the vast savings in dental bills, pain and disease that would accrue from fluoridation.

What followed, according to a book on the subject by Donald R. McNeil, published in 1957 by the Oxford University Press was that fluoridation outran public opinion and scientific conservatism.

A number of scientists believed the consequences of fluoridation had not been sufficiently explored. As recounted by Mr. McNeil, much of the bitterness of the controversy was generated in this period.

Some object to fluoridation on broad philosophical grounds, "We are tampering too much with our chemical environment," they say. "Why take more chances just to save a few dentist's bills?"

There are those, too, who believe that fluoridation is an invasion of civil rights. They accept chlorination of water as unavoidable, since it kills germs that might be lethal. But no one ever dies of a toothache, they say, so why force people to ingest something they find objectionable?

They also resent applying such measures to the entire population, although only children can benefit. There is no reliable evidence that fluorides help teeth after they are grown. Why not give the children pills or milk with fluorides added, they ask.

Public health authorities in general regard these proposals as impractical. Pill-taking, they say, would increase the danger of overdoses. Furthermore, those most in need to aid — the indigent or poorly educated — would be the most likely to overlook such measures, to the detriment of their children.

While the opponents have mustered a number of scientific reports that they believe cast doubt on the safety or effectiveness of fluoridation, these documents do not appear to have impressed the

public health officials. The latter charge that many of these reports are faulty in various ways and, in some cases, are outweighed by contradictory evidence.

Disputed Reports

Among such reports is a 1958 analysis of the American statistical studies by P. R. N. Sutton and Dr. Arthur B. P. Amies of Australia. Their questioning of the American results has allegedly been discredited by other Australian studies.

Another such study is that of Dr. Reuben Feltman, a dentist in Passaic, N.J., who reported that the placentas of mothers became enriched in fluorine when the women had been given a regime of fluoride pills. Critics say all placentas are rich in fluorine.

Still another report cited by the opposition related to the mottling of teeth among children in Qiryat Haiyim, a suburb of Haifa, Israel. The wells of the town produce water with less than one part per million of fluoride. Nevertheless, a survey of children in permanent residence disclosed three with "moderate" mottling, 72 with "mild" or "very mild" effects and 87 with no effect.

The surveyors believed this was too much staining to justify the protection gained. They attributed it to the Israeli diet of tea and fish that is unusually rich in fluorine.

More Drinking Helps

Such factors, they said, also have been recognized in the United States. In Jacksonville, Fla., where more water is drunk because of high heat and humidity, water with 0.6 or 0.7 parts per million seems as effective in curbing decay as the more richly endowed water of some northern cities.

Another report in the armory of the opposition is one by J. T. Marier and his associates at the National Research Council of Canada. It was published last May in the American Medical Association's *Archives of Environmental Health*.

They argued that where fluorides are added to soft water lacking other such substances they may be taken up and stored by the body in excess amounts. In reply, Dr. Francis A. Arnold Jr., director

of the National Institute of Dental Health, notes that the water consumed for many years by those in Colorado Springs was also very soft, apart from its rich fluoride content.

This water was from streams fed by mountain snows, that became fluoridated by flowing over lava beds. No harmful effects, apart from staining, have been observed from lifelong consumption of this water, Dr. Arnold said.

Experiments Discredited

In commenting on the report that sodium fluoride slows the growth of cancer cells, Sir George Godber said that the experiments “bear little or no relation to what actually happens in the body.” His letter was addressed to Dr. Luther Terry, Surgeon General of the United States and his American counterpart.

He pointed out that the fast-growing cancer cells respond quite differently from normal cells. Furthermore, he said, it has been shown that the body exercises discrimination in the amount of fluoride that it absorbs. Thus, it was found that those living in areas where the fluoride in water varies from 0.15 to 2.5 parts per million retained a blood plasma level within the range of 0.14 to 0.19 parts per million.

Only when the intake was at higher levels was the body’s power of discrimination overcome, Sir George said. It is this power that proponents of fluoridation believe protects the body against cell damage or stockpiling of fluorides in dangerous amounts.

New York’s Fluoridation Fuss, 50 Years Later

By Ralph Blumenthal

February 23, 2015

In March 1957, as Elvis was buying Graceland and the Soviets were preparing to shock the world with Sputnik, Robert F. Wagner, the famously cautious mayor of New York, was having trouble taking a stand.

In two days, the city's Board of Estimate would hold a hearing on one of the most contentious issues of the Cold War: whether to begin fluoridation of New York's drinking water, which the Board of Health had urged more than a year earlier to fight cavities. Critics had denounced it as forced medication, dangerously toxic or a Communist plot.

"I need hardly point out what the stakes are," Louis I. Dublin of the Metropolitan Life Insurance Company and former president of the American Public Health Association wrote to a supporter. "A success here will show the way for the rest of the nation. Failure will encourage our opponents in their obstructive tactics resisting public health advances everywhere."

Yet the mayor hesitated. He liked to give problems a chance to go away on their own.

Fluoridation, at one part per million, one milligram per liter, would not come to New York until 1965, after another eight hard-fought years. Now, in this 50th anniversary year, a collection of papers being prepared for scholarly access in the archives of Baruch College's Newman Library has opened a window onto one of history's greatest public health debates.

Even now, the issue continues to divide communities. Portland, Ore., voted down fluoridation in 2013 — for the fourth time — and Israel ended mandatory fluoridation last year. About three-quarters of Americans drink fluoridated water, but the federal Department of Health and Human Services is reviewing a new lower standard for added fluoride, perhaps reducing the recommended level to 0.7 milligrams per liter.

According to the Fluoride Action Network, an organization opposed to fluoridation, the reduction is needed because of "the obvious fact that American children are getting far more fluoride today than they were when fluoridation first began en masse in the 1950s."

Paul Connett, the group's executive director, noted that studies by the Centers for Disease Control and Prevention have found that about 40 percent of teenagers now display dental fluorosis, or

mottling on teeth caused by high fluoride levels. That percentage has doubled in less than 20 years.

The C.D.C. denies any backtracking from support of fluoridation out of health concerns. “Not at all,” said Linda S. Orgain, a C.D.C. spokeswoman. She called the proposed decrease for added fluoride, first published in the *Federal Register* in 2011, “a response to differing conditions today” when children are getting fluoride from various sources, including toothpaste.

The fluoridation files at Baruch document efforts to sway Wagner and other city officials. The records are part of a collection of the influential but now-defunct Institute of Public Administration and its longtime director, Luther Halsey Gulick, a key adviser to President Franklin D. Roosevelt and Wagner.

The roots of the controversy go back to the early 20th century, when researchers noticed that teeth mottled by high levels of natural fluoride resisted cavities. Studies concluded that water fluoridated at one part per million safely reduced tooth decay in children by some 60 percent. By 1954, 20 million Americans were drinking fluoridated water in Baltimore, Washington, Miami, San Francisco and other major cities.

The New York City health commissioner, Leona Baumgartner, recommended joining them, and the Board of Health gave its approval two years later.

Out of a 1956 City Council hearing grew a powerful advocacy group, the Committee to Protect Our Children’s Teeth, led by the noted pediatrician Dr. Benjamin Spock. Members included Eleanor Roosevelt, Jackie Robinson, former Governor Herbert H. Lehman, the commentator H.V. Kaltenborn and the labor leaders George Meany and Walter P. Reuther.

Gulick was recruited for his mastery of public administration. Born in Japan in 1892 to a prominent missionary family, he had trained alongside Robert Moses at the New York Bureau of Municipal Research, a Progressive Era reform group that had pioneered municipal budgets, performance audits and accountable govern-

ment. He had worked on the Brownlow Committee, which streamlined the federal bureaucracy for Roosevelt, and he had unsnarled production and refugee crises in World War II.

Advocates of fluoridation distributed a 25-cent booklet, “Water Fluoridation: Facts, not Myths,” that portrayed the controversy as “a technical debate” over fluoride’s efficacy and safety, already resolved by science, including 10-year field trials in Newburgh, N.Y., and Grand Rapids, Mich. The booklet marveled that fluoridation was attracting “nearly as much citizen attention as juvenile delinquency, education, automobile accidents or the hydrogen bomb.”

To prepare for a marathon hearing on March 6, 1957, before the city’s Board of Estimate, Gulick and his associates got 375 scientists to assemble evidence on fluoride’s safety and compiled a list of friendly witnesses, including a mother from each of the five boroughs, as well as Harold C. Hodge, a professor of pharmacology at the University of Rochester and an early booster of fluoridation.

Opponents of fluoridation later accused Dr. Hodge of not disclosing controversial experiments on fluoride toxicity conducted during the Manhattan Project; supporters said the small amounts used in drinking water were proven safe.

Gulick focused on Wagner, plying him with draft statements supporting fluoridation and a legal memo arguing that the City Charter prohibited the referendum that opponents were demanding and that supporters feared would play to public fears.

The mayor needed to stand up, Gulick warned. “If you don’t, a great many of your best and most respected backers will think you are lacking in clear thinking and courage.”

Monroe Goldwater, a powerful Democrat and a leader of Jewish relief efforts during World War II, lobbied Wagner along with soon-to-be Republican Governor Nelson A. Rockefeller. Gulick preferred to act alone. “I can do my part with the mayor more effectively at some other time and individually,” he wrote to Henry H. Urrows of the Committee to Protect Our Children’s Teeth.

After the raucous 15-hour hearing, Gulick followed with a strongly

argued brief in favor of fluoridation to City Council President Abe Stark. Gulick arranged for it to be reprinted in *Public Administration Review* and sent a copy to Wagner with the note: “Dear Bob, you will want this for your files. Perhaps you will want to look it over.”

For the next six years, nothing happened. On Nov. 18, 1963, the City Council and the Board of Estimate held another public hearing. Again, hundreds thronged City Hall to testify, cheer and boo. Then, at last, fluoridation was set.

But in October 1964, Wagner’s water commissioner delivered bad news: It was hard to get the chemicals. It took a year before the fluoride and feeder devices were ready. Finally, in October 1965, fluoridated water began flowing through the city’s taps. By then the city was ready to elect a new mayor, John V. Lindsay.

One of the arguments mentioned in the 1960s debate on fluoridating New York City’s water was based on a faulty understanding of who could be helped in dental caries reduction with an implementation of communal water fluoridation. Based on a belief that only children can benefit, why then should such measures be applied to an entire population? As is now well understood, however, the effect of fluoride is strongest post-eruptive rather than pre-eruptive. Evidence for this has been around for some time — for example, in the preliminary results for the Grand Rapids fluoridation trial, an effect of caries reduction for already calcified teeth was explicitly noted. Caries are caused by the action of acids on tooth enamel that are produced when sugars in food react with bacteria present in the dental plaque on the tooth surfaces. This caries producing process is called demineralization; the presence of fluoride in the oral cavity can both inhibit demineralization, and enhance remineralization and the healing of possible carious incursions. Some of this process was

studied explicitly in the Tiel-Culemborg experimental trials in the Netherlands where individuals were followed longitudinally.

As noted earlier, the protective properties of fluoride were initially thought to be solely because of changes in enamel during tooth development. This was a reasonable inference at the time based on the observed relationship between fluoride and cosmetic fluorosis. There was also a belief that fluoride was incorporated into the enamel during tooth development and this would result in a more acid-resistant mineral. It was only later work that suggested fluoride acted to prevent caries primarily post-eruptively although some pre-eruptive effects were still present. The action of fluoride being mainly topical meant that both adults and children benefited from the presence of fluoride in the oral cavity where demineralization was inhibited, remineralization was enhanced, and bacterial activity in dental plaque was curtailed. This might be used as another example of a correct outcome occurring although the process by which something happens was not initially understood correctly — the wrong mechanism but the right result.

WHERE COMMUNAL WATER FLUORIDATION STANDS TODAY —

This concluding section reviews several of the issues that seem to be raised perpetually about the safety and advisability of communal water fluoridation. The anti-fluoridation forces remain strong to this day even though all of their concerns have been addressed satisfactorily and repeatedly over the years through numerous studies and reviews conducted under the auspices of all major national and international medical and dental associations, and by reputable governmental agencies such as the National Academy of Sciences. One particularly comprehensive and up-to-date source summarizing the current understanding of fluoridation is from the American Dental Association and its publication, *Fluoridation Facts* (2018), arranged as a series of questions and answers about fluoridation benefits, safety, practice, cost, and public policy. The first item under safety, for example, begins as follows:

Does fluoride in the water supply, at the levels recommended for the prevention of tooth decay, adversely affect human health?

Answer: The overwhelming weight of scientific evidence supports the safety of community water fluoridation.

Fact: For generations, millions of people have lived in areas where fluoride is found naturally in drinking water in concentrations as high or higher than the optimal level recommended to prevent tooth decay. Research conducted among these persons confirms the safety of fluoride in the water supply.

As with other nutrients, fluoride is safe and effective when used and consumed as recommended. No charge against the benefits and safety of fluoridation has ever been substantiated by generally accepted scientific knowledge.

When done properly, the addition of fluoride to the communal water

supply reduces the occurrence of dental caries dramatically and does so across the life span. Moreover, there is no credible evidence that fluoridation leads to any major medical downsides such as cancer, Alzheimer's disease, diabetes, osteoporosis, lowered IQ, and so on. The minor dental fluorosis that may be present in a small proportion of the population is typically cosmetic. And even this minor fluorosis can be mitigated further by adopting the newly recommended fluoridation standard of 0.7 ppm, assuming that fluoride obtained from other sources, such as toothpaste, allows such a reduction in the level of communal water fluoridation without any degradation in caries protection. For those old enough to remember, there are the black and white television ads for Crest toothpaste going back to the 1960s that touted "Look, Ma, no cavities"; these indicated clearly that communal water fluoridation was not the only available source of protective fluoride.

Against this backdrop of wide-spread medical and scientific affirmation for communal water fluoridation, it may be surprising to some that there are still bitter fights being waged against existing fluoridation efforts, and especially for any new proposals that may arise in municipalities considering its adoption. To see the depth of the anti-fluoridation opposition, a visit to the web site for the Fluoride Action Network is probably all one really needs to do. Here, most of the specious arguments against fluoridation find a sympathetic home. As it has been for many other fringe groups, the internet is a boon for the anti-fluoridation forces. This is a place to peddle misinformation and "junk science," and to perpetuate the mistaken illusion that there is still an open debate and scientific controversy about the safety of fluoridation — there simply isn't. Several of the

more broadly-based arguments of those opposed to fluoridation will be reviewed below; at first reading, a few may even have superficially appealing rationales.

Some of the most disingenuous arguments against fluoridation ignore the issue of dosage and state that because fluoride is an (insidious) poison when used at a high level, no amount can ever be safe, even at the 1.0 ppm typically set for communal water fluoridation. As has been documented repeatedly, this is a level that produces minimal fluorosis, if any. An early and prominent example of this kind of (mis)reasoning that persists to the present is in the 1953 monograph by Leo Spira, *The Drama of Fluorine: Arch Enemy of Mankind*. Spira's argument goes something like this: aluminum cookware is produced with the mineral cryolite in the smelting process; cryolite contains fluorine in some combined form, and therefore, fluorine must leech into whatever we eat when the cooking is done with aluminum. This remains true even though one might also obtain additional exacerbating fluoride through naturally or artificially fluoridated drinking water. The presence of fluorosis (or mottling) is an all-or-none condition, and when present to any degree whatsoever, it is an undeniable sign of chronic fluorine poisoning. In turn, chronic fluorine poisoning leads to all sorts of conditions — obstinate constipation, boils, eczema, sensations of “pins and needles,” ectodermal lesions of all sorts, and so on. Thus, if we stop drinking fluoridated water or eating food prepared in aluminum cookware, the presenting medical condition, whatever it may be, will just go away. A short quote from the Spira monograph shows this pattern of reasoning:

It has already been explained that mottling of the teeth is the result of drinking a water containing a concentration of at least

1 part per million of fluorine ingested during the first 8 years of life. Mottling of the teeth is not a localized lesion, but the first visible, external sign of chronic fluorine poisoning produced via the general blood circulation. These facts are firmly established, and no attempt will ever succeed in explaining them away. On them will henceforth rest the study of every other aspect of the problem.

This type of argumentation is at best an aborted form of abductive reasoning: the surprising condition, say, of dermal lesions is observed; this person drinks fluoridated water and/or eats food from aluminum cookware; therefore, fluorine must be the cause of the dermal lesions, and avoiding the fluoridated water/aluminum cookware will make the lesions go away. If a regimen of no fluoridated water or aluminum cookware is instituted and the dermal lesions somehow disappear (presumably by themselves, over a period of time), the causal relation is therefore conclusively established between fluorine at any dosage level and the presenting medical condition, whatever that condition may be.

Besides falling prey to the Latin-phrased fallacy: *post hoc ergo propter hoc* (after this, therefore because of this), Spira's complete disregard of any consideration of dosage invalidates his argumentation from the start. As far back as the early 1500s, the issue of dosage was apparent to Paracelsus (1493–1541) and his contemporaries. As a “father of toxicology,” Paracelsus is known for various quotes regarding dosage levels and poisonous effects. In English, there are the phrases: “solely the dose determines that a thing is not a poison”; “only the dose makes the poison”; or in German, the classic toxicology maxim can be stated as: “Alle Dinge sind Gift und nichts ist ohne Gift; allein die Dosis macht, dass ein Ding kein Gift ist”; or in English, “all things are poisonous and nothing is without poison;

only the dose makes a thing not poisonous.”

A dark side of abductive reasoning which asserts that if something could be true, it is, leads to many of the successes that the anti-fluoridation forces have had when faced with a community referendum on fluoridation. If one can point to an apparent (even through almost surely spurious) increased association between a dread medical condition (such as cancer, Down’s syndrome, and the like), and the presence of fluoridation in the communities studied, then why take the risks involved in adopting fluoridation? Even though the probability of a casual link between fluoridation and, say, some form of cancer may be minuscule, the “cost” incurred if it is true is usually viewed as so much greater than the benefit of a small reduction in the presence of caries for a community, that voters may not wish to assume the risk, and the referendum goes down in defeat. In general, questions that have a scientific basis are beyond the competence of a referendum to resolve.

One of the general tactics of those opposed to fluoridation is to equate communal water fluoridation with things that people may viscerally feel are bad. In other words, we have the classic “guilt by association.” For example, in the news item from the *Santa Fe New Mexican* that began this chapter, there are several such equivalencies made: fluoridation amounts to dumping an additional pollutant into the environment; or that pro-fluoridation appeals are just like those of the tobacco companies saying that smoking has no ill effects. Also, remember when it was considered harmless to add lead to our gasoline or to interior house paint that is then inadvertently ingested by infants; these past practices still have various medical consequences to this current date. There are many other such con-

nections the anti-fluoridation forces try to make when they mount their campaigns: fluoridation is massed and forced medication and fails the solemn principle of informed consent; the government does not have the right to force individuals to take a medication against their wishes; fluoridation is (or will lead to) socialized or totalitarian medicine, and represents an unacceptable governmental intrusion; because the predominant benefit of fluoride is topical and not systemic, the practice of forcing people to ingest fluoride has become even more absurd; when communities fluoridate their water, they are doing to the whole community what an individual doctor is not allowed to do to anyone – prescribe medication without the individual’s informed consent.

Some of the more entertaining of the anti-fluoridation arguments, if you can call them that, amount to conspiracy theories or myths that are widely perpetuated but which are just not true. Thus, we have the need of phosphate fertilizer companies and others to get rid of their toxic waste byproducts that contain fluorides. What better solution than to actually profit from toxic waste products by selling them to gullible communities? Always remember the adage of “follow the money,” to see who benefits. Or because of a military-industrial conspiracy that exists in North America, it is necessary to eliminate the enormous amount of toxic waste generated by the nuclear weapons industry that goes all the way back to the Manhattan Project during World War II — and what better way to do this than by dumping it into the nation’s water supply. The sugar industry has also been seen as guilty in promoting communal water fluoridation because of their need to sell lots of sugar and the role that sugar plays in caries formation. As an indication of the type of collusion

hypothesized between industry and various governmental agencies, Frederick Exner in his 1961 book, *The American Fluoridation Experiment*, notes the connection between a town called Longview and a nearby polluting aluminum factory:

At Longview, the people voted down fluoridation in 1952. A few years later, children started to show mottled teeth ...; whereupon the Council put in fluoridation without a vote. Now the mottling can be blamed on the water rather than the aluminum plant.

Generally, various forms of disparaging innuendo serve the conspiracy theorists well in their promotion of sinister plots concerning fluoridation. The toxic waste from the fertilizer industry leads obviously to the scourge that fluoridation brings with it; or the conspiracy that is clearly reflected by an individual sitting on the board of directors of, say, ALCOA, who has a third cousin serving on a stacked National Research Council review panel for fluoridation; or for the label of “censorship” to be attached to the National Institutes of Health and associated governmental agencies that are all guilty of endorsing fluoridation and employing peer reviewers on grants administered by their agencies, and who regularly reject as “junk science” the anti-fluoridation forces paranoid ramblings.

A perennially difficult conspiracy theory to debunk is that water fluoridation started in the ghettos and death camps of Nazi Germany, and was used to pacify the Jews and other undesirable people. In the quotes from Jack D. Ripper that started this chapter, there is the contention that fluoridation is also a communist plot designed to rob us of our precious bodily fluids so that the communists can take over the United States. Or, anti-Semitically, fluoridation is a Jewish plot meant to weaken the Aryan race both mentally and spiritually. As an

example of this kind of reasoning, several statements are given below quoted by Ian Stephens in the pamphlet, *The Dickinson Statement: A Mind Boggling Thesis*:

At the end of the second world war, the United States Government sent Charles E. Perkins, a research worker in chemistry, biochemistry, physiology and pathology, to take charge of the vast Farben chemical plants in Germany.

While there he was told by German chemists of a scheme which had been worked out by them during the war, and adopted by the German General Staff.

This was to control the population in any given area, through mass medication of drinking water. In this scheme sodium fluoride occupied a prominent place.

Repeated doses of infinitesimal amounts of fluoride will in time reduce an individual's power to resist domination by slowly poisoning and narcotizing a certain area of the brain and will thus make him submissive to the will of those who wish to govern him. Both the Germans and the Russians added sodium fluoride to the drinking water of prisoners of war to make them stupid and docile.

...

We are told by the fanatical ideologists who are advocating the fluoridation of the water supplies in this country that their purpose is to reduce the incidence of tooth decay in children, and it is the plausibility of this excuse, plus the gullibility of the public and the cupidity of public officials that is responsible for the present spread of artificial water fluoridation in this country.

However – and I want to make this very definite and positive – the real reason behind water fluoridation [is] not to benefit children's teeth. If this were the real reason, there are many ways in which it could be done which are much easier, cheaper and far more effective. The real purpose behind water fluoridation is to reduce the resistance of the masses to domination and control and loss of liberty.

When the Nazis, under Hitler, decided to go into Poland ... the German General Staff and the Russian General Staff exchanged scientific and military ideas, plans and personnel and the scheme of mass control through water medication was seized upon by the Russian Communists because it fitted ideally into their plan to communise [sic] the world ...

I say this in all earnestness and sincerity of a scientist who has spent nearly 20 years research into the chemistry, bio-chemistry, physiology and pathology of fluorine: any person who drinks artificially fluorinated water for a period of one year or more will never again be the same person, mentally or physically.

In addition to the various hysterical conspiracy theories, there are several other categories of argumentation and language usage employed by those opposed by fluoridation that should be noted. One such category includes statements that are just not true or for which there is no credible evidence whatsoever. We have seen several of these already: fluoridation only works for the very young; fluoridation is outdated and much better mechanisms are now available for providing fluoride to the oral cavity; economically, it would be more cost-effective to just give the money spent on fluoridation directly to dental clinics for the poor; or rather blatantly, fluoridation just does not work to reduce caries prevalence; fluoridation leads to lower IQs and calcifies the pineal gland in the brain; fluoridation is poor medical practice; the fluorides derived from hazardous waste products from the phosphate fertilizer industry are not pharmaceutical grade (whatever that means); fluoridation is an attempt by industry to camouflage their deadliest pollutant; fluoridation is pharmacologically obsolete; fluoride falls into the same category as DDT.

A second large grouping of statements from those opposed to fluo-

ridation are merely statements of personal opinion without any corroborating credible evidence: fluoridation is “one of the great scientific frauds done to the unsuspecting public” (says Helen Oates of Santa Fe); “the science of investigation was replaced by the politics of promotion”; [name a medical condition] is a manifestation of systemic fluoride poisoning; the decision to fluoridate does not provide an adequate margin of safety to protect everyone in the population, especially the most vulnerable; the dose cannot be controlled nor can who gets it; a child with mottled teeth is a poisoned child; we are messing too much with our chemical environment.

A third type of argumentation employs various pejorative adjectives or phrases that express contempt and disapproval, and which are intended to provide the argument against fluoridation just by their use. Some of these follow without further comment: the pestilence of fluoridation; hell-bent pro-fluoridation forces; forced fluoridation; people have been lured; rubber stamped; so-called; fluoridation zealot; follow-the-leader approach to public health and dentistry; most prescribed medicine in the United States; arsenic-contaminated fluoridating chemicals; missionary zeal; spin doctors; sow the idea; influential propagandists; hardly a disinterested source; protected pollutant; patently ludicrous; the fox guarding the chicken coop; locking the barn door after the horse has escaped; Great Fluoridation Gamble; self-serving governmental reviews; panels stacked with pro-fluoridation experts; purportedly to fight tooth decay; should convince the independent observer that the risks far outweigh the benefits; exposing a whole population to a toxic substance; fluoride is being crammed down our throats; administratively mandated fluoridated water (per Ralph Nader); fluoridation amounts to an article

of faith administered by godless medical technocrats.

A fourth category of language usage that passes for argumentation among those opposed to fluoridation is to provide different completions for the phrase stem “fluoride is,” and hopefully, to lead the reader or listener to the conclusion that fluoridation is basically bad, even though the completion by itself does not imply anything nefarious. Here are several examples: ... fluoride (fluorine) is ... a hazardous toxic waste; not an essential nutrient (true, but how about a “beneficial” nutrient?); not tied to any disease of “fluoride deficiency”; part of anti-depressants such as Prozac; a rat poison; part of Sarin nerve gas; a neurotoxin; not approved by the FDA for ingestion; and last, no federal agency accepts responsibility for the safety of fluorine (nor we might add, for any other chemical element of nature). Alternatively, to use a stem of “fluoridation is” ... not a targeted approach to caries prevention, and everyone in the community is reached (which may be the greatest strength of fluoridation as well as its greatest weakness in terms of social policy).

Another common tactic based on language usage is the incorporation of non-refutable phrases into what passes for some type fluoridation critique. Here are several common examples: ... failure to refute the [blank] study; a possible link; fluoride may increase [blank] in the [blank]; it is likely that larger studies would show; a connection is plausible; may cause [blank] because fluoride builds up in [blank]. And in general, fluoridation may lower, cause, increase, lead to, exacerbate, worsen, aggravate, magnify, and so on.

The anti-fluoridation forces point to assumed flaws in some of the quasi-experimental trials of communal water fluoridation, such as in the first one in Grand Rapids/Muskegon. Several of these can be

readily acknowledged, such as the blinding of dental investigators as to which communities individuals belonged to. But the magnitude of the effects seen, the replications over other experimental/control city pairs, and the now seventy-odd years of communal water fluoridation from the time of these initial trials leaves no doubt as to the safety and effectiveness of communal water fluoridation in reducing the presence of caries in a community. Given my birth year of 1944 and where I grew up, I did not benefit from any communal water fluoridation, and my teeth show it, both then and now. My own children, however, who did grow up in fluoridated communities, are blessed with caries-free teeth — but this is clearly not genetic.

There are a few other devices that those opposed to fluoridation use to further their campaigns. One is to give a “slippery-slope” argument: first, the water is fluoridated; then, birth control medicine is added to the communal water supply to control the growth of the population. A second strategy is to use an ecological correlation to infer an individual-level causal relationship. For example, the fact that groups of individuals in fluoridated cities generally have a higher incidence of, say, bladder cancer, can’t be used directly to infer that a causal link exists between bladder cancer and fluoridation at the individual level. Such an inference is generally called an “ecological fallacy,” for which an enormous literature exists. Generally, one cannot infer an individual level relationship from an association seen at a group level (without, at least, making enormously heroic assumptions). What typically happens when other differentiating factors are taken into account (such as age, sex, race, ethnic grouping, socioeconomic status, and so on), an association seen at the group level just disappears.

A final argument of the anti-fluoridation forces is to invoke what is called the precautionary principle which states that if there is not a complete consensus about the risks involved in taking some action or invoking some policy, then that action or policy should be delayed or deferred until such a consensus can be reached. More “down-to-earth” versions of the precautionary principle would be: “better safe than sorry”; “look before you leap”; “an ounce of prevention is worth a pound of cure”; “it is always best to err on the side of caution”; “why take more chances than necessary to save a few bucks on dentist bills”; “if in doubt, vote it out”; and so on. As evidence that the precautionary principle was inappropriately disregarded, the anti-fluoridation forces point to the Public Health Service and American Dental Association endorsing fluoridation in the early 1950s before the various trials, such as in Grand Rapids and Muskegon, were completely finished. This stance ignores the enormous amount of supporting evidence available from the early 1900s as well as the overwhelming consistency of results from Grand Rapids and elsewhere during the first years of the experimental trials — so much so that Muskegon dropped out as a control city and began fluoridating its communal water supply in 1951 before the first interim report was formally published in 1953. The dramatic preliminary results that lead to the initialization of fluoridation in Muskegon had been available much earlier to the city. Those who favor communal water fluoridation would argue that such a consensus about safety and effectiveness already exists, and then reiterate the view that communal water fluoridation represents one of the ten greatest public health achievements of the twentieth century.

There are several positive arguments for fluoridation that could

also be mounted although these don't seem to have the same "hair on fire" effects as do those produced in the anti-fluoridation narrative. For example, the most convincing evidence the pro-fluoridation forces have is the hundred-odd years of data on the effects of both naturally and artificially occurring communal water fluoridation. The one acknowledged downside that could be pointed to, is a minimal dental fluorosis that may be present in a small proportion of the population. But even this can be mitigated by adopting a lowered fluoridation standard of 0.7 ppm, and trusting that some other sources of fluoride are available in what we eat or apply to our oral cavities.

Another level of argument in favor of communal water fluoridation would go something like this: consider a medical trial for a "new" medicine against a given dread disease that uses a control group whose members also have the disease but who only receive an inert placebo. As soon as the positive effects of the new "medicine" appear (assuming they do), it is unethical to deny the control group the effective medication (witness the unethical Tuskegee syphilis experiments from the 1930s to the 1970s conducted by the U.S. Public Health Service). The same could be argued for fluoridation: because fluoridation is known to be effective in reducing caries and the various unfortunate dental conditions that can result, it is unethical to deny such an intervention to a community. Water fluoridation is especially beneficial in communities of generally lower socioeconomic status that have a disproportionate share of dental caries and generally less access to dental care and other sources of fluoride. As always, with knowledge comes responsibility.

A FINAL NOTE —

One line of argument sometimes used by those opposed to fluoridation is to revive an old Roman adage of “what touches all must be approved by all.” On its face, this might seem a reasonable principle to follow, but only if it is adopted at some level of majority rule. Although all might agree to abide by the results of a referendum on fluoridation, it is incumbent on an individual who does not wish to partake in the fluoridation effort to find alternative sources of fluoride-free water. Or, conversely, in an area of fluoride-free water, to use whatever fluoride rinses and/or tooth pastes that will help protect a family’s oral cavities. What we all should resent, however, is the lack of appropriate fluoridation in a communal water supply because of a few misinformed and misguided members of a controlling governmental agency. To state this bluntly, the unfounded fears of the few should not take precedence over the greater good of the many. In my view, successful anti-fluoridation efforts do a major disservice to a city and especially to its most vulnerable residents who don’t regularly receive an appropriate amount of fluoride in what they consume or have the level of preventative dental care they should be receiving. The safety and effectiveness of water fluoridation has been evaluated frequently; and there is still no credible evidence that supports an association between fluoridation and any of the dread conditions hypothesized by those opposed to fluoridation. Anti-fluoridation forces are good at selecting studies that put their dishonest contentions in a positive light, or in only reporting chance-induced results supportive of whatever position is being taken, and ignoring everything else.

Further Reading and References:

There are a number of sources that can be suggested to fill in further details about the story of fluoridation. We provide several of these in this final section that were relied on heavily in preparing this chapter.

William A. Douglas, *A History of Dentistry in Colorado (1859–1956)*, 1959, Johnson Publishing Co., Boulder, Colorado.

Note, in particular, Chapter 9, “From Colorado Brown Stain to Fluoridation” (pp. 186–214). This chapter, for example, reprints the letter from H.V. Churchill to Frederick McKay on finding a high level of fluoride in the Bauxite water supply.

J.J. Murray, A.J. Rugg-Gunn, and G.N. Jenkins, *Fluorides in Caries Formation*, 1991 (Third Edition), Butterworth-Heinemann Ltd., Oxford, England.

This is a comprehensive technical text on both the history of fluoridation and how it acts to reduce caries and tooth decay — a thorough review of the science behind fluoridation.

American Dental Association, *Fluoridation Facts*, 2018.

This is a readable and comprehensive introduction to several aspects of fluoridation posed in a question/answer format. Areas covered are Benefits, Safety, Fluoridation Practice, Public Policy, and Cost.

Donald R. McNeil, *The Fight for Fluoridation*, 1957, Oxford University Press.

Frank J. McClure, *Water Fluoridation: The Search and the*

Victory, 1970, National Institute of Dental Research, Bethesda, Maryland.

These are the two most indispensable texts for the chapter. The book by McNeil is written from a historical perspective, and is based on original manuscripts and the correspondence of McKay, Black, Dean, and others, plus extensive interviews with various principals including McKay and Dean. McClure's text, although partly historical like McNeil's book, is more data and evidence oriented, and consistent with what a data scientist today might expect in presenting the cumulative case for communal water fluoridation.

R. Allan Freeze and Jay H. Lehr, *The Fluoride Wars*, 2009, Wiley, Hoboken, New Jersey.

This is a thorough social and political history of fluoridation that reflects its subtitle well: "How a modest public health measure became America's longest-running political melodrama."

Paul Connett, James Beck, and H.S. Micklem, *The Case Against Fluoride*, 2010, Chelsea Green Publishing, White River Junction, Vermont.

This is the only anti-fluoridation book listed here (although several others are given in the text of the paper itself). The main author, Paul Connett, is also the chief architect of the Fluoride Action Network.

Finally, an open access review article by Jason Armfield appearing in *Australia and New Zealand Health Policy* (2007), provides a comprehensive antidote to the Connett et al. book: "When Public Action Undermines Public Health: A Critical Examination of Anti-fluoridationist Literature."