Relationship of Lithium Metabolism to Mental Hospital Admission and Homicide

E. B. DAWSON, Ph. D., T. D. MOORE, B.S., and W. J. McGANITY, M.D.

Introduction

Clinical studies have demonstrated the effectiveness of therapeutic dosages (either orally or parentally) of lithium, as lithium carbonate, for manic-depressive psychotics[1] schizoaffective schizophrenics, patients with associated behavior-disorders, epileptics, and women with premenstrual tension and depression syndrome[2]. Sheard recently reported lithium to be effective in controlling episodic rage among prisoners[3] indicating some forms of criminal behavior may be related to lithium dependent mental illness. Indeed, criminal agression and neurotic ideology has been attributed to psychoneurosis.[4-8]

The biochemical pathways of lithium's therapeutic activity is not clear; however, reports indicate that it is the only metal ion which stimulates oxidative metabolism in the brain cortex in a sodium-free medium.[9,10] The metabolism of lithium is known to be associated with that of sodium, potassium, and water[11,12]. Isotope studies have shown that when ingested, lithium is assimilated rapidly (over 99%) against a concentration gradient of both sodium and potassium[13], and is ultimately excreted by the kidneys[2,14]. Thus, continuous intake at any levels will be reflected in urine levels.

We have previously reported a mathematical correlation between municipal drinking water lithium levels and both the incidence and rates of admission to state mental hospitals in Texas.[15] The apparent lithium ion effect was found to be suited to those patients admitted for neurosis, psychosis (other than schizophrenia), and personality problems. The county admission rates, rainfall, and drinking water lithium levels followed a geographical distribution across the state.

The soils of those areas of Texas containing high water levels of lithium are known to be saturated with lithium salts[16,17], and these regions are the sources of rivers which drain from west to east and empty into the Gulf of Mexico[18].

Virtually all ground water in Texas results from rain which originates as moisture carried by prevailing winds from the Gulf of Mexico, and falls predominantly in the eastern part of the state. It is this rainfall that washes the lithium from the soils and dilutes the surface water lithium levels. The apparent relationship between rainfall and lithium levels in drinking water as well as mental admission may thus be explained.

At the time of our initial report[15], we anticipated measuring the plasma or urine lithium levels of the subjects in the Texas Nutrition Survey of 1968 to establish a relationship between drinking water and body lithium levels. Further, it was considered desirable to determine a possible relationship between body lithium levels and admission to mental hospitals. The present study does show significant interrelationships between the urinary and drinking water levels of lithium, as well as each of them to state mental hospitals admissions, and annual rainfall. In addition, a statistical relationship is shown between the incident of homicide and lithium concentration in either the water or urine.

Material and Methods

The urine samples used in this study were obtained during the summer and fall of 1968 in the Texas Nutrition Survey[19]. Prior to the survey, a three-step sampling process identified 103 enumeration districts—portions of the 1960 U. S. census tracts in which the average income level in 1960 was within the lower 25 per cent of the economic scale. There were 200 of the 254 counties in Texas eligible

From Department of Obstetrics and Gynecology and Texas Nutrition Survey Team, University of Texas Medical Branch, Galveston, Texas.

Supported by Public Health Service Grant PH 86-68-123.

in this selection. Twenty six counties were chosen which represented the urban, rural, regional, and ethnic characteristics of the state. Anderson, Bexar, Cameron, Dallas, Dimmit, Duval, El Paso, Frio, Guadalupe, Hardin, Harris, Haskell, Hidalgo, Jones, Lampasas, Limestone, McLennan, Newton, Nueces, San Patricio, Tarrant, Travis, Uvalde, Washington, and Wichita. The number of enumeration districts per county was proportional to the per cent of the population at risk. All subjects were members of families and most of the families had resided in their respective communities for over ten years. Their ages ranged from 6 months to 97 years and over 3400 individual urine samples were obtained from these selected subjects.

A temporary field laboratory and examination center was established in each location usually in a centrally located school building. Multiple tap water samples were obtained from the local water supply and immediately shipped with the blood and urine samples to our base biochemical laboratory at the University of Texas Medical Branch, Galveston, Texas. Lithium levels in water and urine were determined with a Perkin-Elmer Epectrophotometer, Model 303, equipped with a Recorder Readout. Attempts to measure plasma lithium proved futile, probably due to the low levels present. The water lithium levels have been expressed as μg/liter (parts per billion). In order to compensate for variations in the individual random specimens of urine, creatinine levels were determined in the urine by the method of Folin and Wu[20] and all urine concentrations of lithium have been expressed as μg/Gm. of creatinine.

Annual state mental hospital admission reports were obtained from the Texas Department of Mental Health and Mental Retardation. These reports summarized the number of annual admissions (first, subsequet, readmissions, and total admissions) and admitting diagnoses from each of the 254 counties in Texas. The admission diagnoses were tabulated according to the county of residence of the patient. To compare admission and diagnostic data concurrently with the time of the water and urine sampling two annual reports were used—1 September, 1967 to 31 August, 1968[21] and 1 September 1968 through 31 August, 1969.[22]

All diagnoses of the forms of mental illness admitted to the state mental hospitals were by the resident staff of each hospital. There could have been no forethought of a lithium comparison on the part of the staff physicians for the simple reason the idea was not conceived until several years after their hospital reports were forwarded to the Texas Department of Mental Health and Mental Retardation, and the data recorded on IBM computer equipment.

The admission and diagnostic data were coded for the computers according to the 1968 Edition of the Diagnostic and Statistical Manual of mental disorders (American Psychiatric Association, Washington, D. C.). The diagnostic computer codes included in this report were:

Diagnosis:

A. Schizophrenia; (includes simple, hebephrenic, excited catatonic, withdrawn catatonic, paranoid, acute episodic. latent, residual, excited schizo-affective, depressed schizo-affective, childhood, undifferentiated chronic, and unspecified)	295.0-295.99
B. Psychosis:	
Senile and presenile dementia	290.0-290.1
Alcoholic psychoses	291.0-291.9
Associated with intracranial infection	292.0-292.9
Associated with other cerebral conditions	293.0-293.9
Associated with other physical conditions	294.0-294.8
Involutional melancholias	296.0-296.9
Paranoid states	297.0-297.9
Other psychoses	298.0-298.9
Unspecified psychoses	299.0
C. Neurosis; (includes, anxiety, hysterical, conversion hysterical, dissociative hysterical, phobic, obsessive compulsive, depressive, depersonalization, hypochondriacol, other, and unspecified)	300.0-300.9
D. Personality disorders;	
Paranoid types	301.0-301.9
Sexual deviations	302.0-302.9
Psychophysiologic	305.0-305.9
Special Symptoms	306.0-306.9
Transient situational disturbances	307.0-307.4
Childhood and adolescence	308.0-308.9

The number of admissions (first, secondary, and total) and the admitting diagnoses were calculated as rates per capita. In each of the 26 counties surveyed, the county population base for 1968 and 1969 was derived from their 1960[23] and 1970[24] census. Each rate of county admission as well as each category of diagnostic incidence was divided by the calculated population to obtain the rates of admission and diagnoses per unit of population. The admissions were based on per 10,000 people. Both the admission and diagnostic rates for the two years were averaged to obtain a single rate representative of the two year period and encompassing the time of our lithium urine and water sampling. However, it must be noted that the rates for each individual county were very similar for both years.

Data from two counties were omitted from further consideration. Customarily, in each county surveyed, the county seat and at least one predominantly rural community were considered as representative of a county. However, Harlingen, in lieu of Brownsville was surveyed in Cameron county. Consequently, there was no population sampling representative of the largest municipality (county seat). The data from Lampasas county, and Lampasas city, the county seat, were excluded because a large number of residents obtained their drinking water from private wells. In addition, the municipal water facilities were being enlarged and the water source was further altered at the time of the survey. In Hidalgo County, the cities of Donna, Weslaco, and Mercedes (total population 32,345 in 1968) all had a common water supply. Each community was included in the Nutrition Survey. Their average water and urine lithium measurements have been consolidated and are included in this report as Weslaco, the central community.

The vast majority of the population in each of the 25 counties in this study were found to be concentrated in large metropolitan county seats, 88% of the total county populations as of 1968. These same communities were also the place of residencies of virtually all patients admitted to state mental hospitals from the county. Therefore, urine lithium levels from the residents of the county seats have been used for comparisons with their mental admission data. Furthermore, only urine measurements from subjects over 16 years have been included in the present study in as much as the creatinine excretion gradually changes from birth to maturity.[25] Our population of 860 adult subjects whose urine samples were used for this report averaged 38 years of age each had been a resident of their county for more than 10 years.

The county admission and diagnostic rates have been compared after being grouped in equal distributive ranges according to (1) the lithium levels of the local drinking water, (2) the mean urinary lithium levels among residents of that locale and, (3) mean annual rainfall of the counties.[26]

The Students "t" test was used to determine the statistical significance of differences in mean values of county admission (first, secondary, and total) and diagnostic rates when grouped according to high and low levels of: (1) lithium level of the drinking water ($\leqslant$ 11.0 μg/L. versus $\geqslant$ 70.0 μg/L.). (2) mean lithium levels of the urine samples from the residents ($\leqslant$ 110 versus $\geqslant$ 240 μg/Gm. creatinine), and (3) mean annual rainfall of these counties ($\leqslant$25 versus $\geqslant$ 35 inches per year). The product moment correlation "r" was used to determine the statistical significance between simultaneous differences in all 24 data values of the items under study.

Annual county rates of death due to homicide and suicide (self murder) were calculated for 1968 and 1969 based on the incidences per county divided by the calculated population per county for those two years, and converted to a common population divisor of 10,000 people. The county incidences were published in the 1968 and 1969 Texas Vital Statistics[27,28] by the Texas State Department of Health and were based on death certificates forwarded to the department by county officers. These certificates provide no information regarding mental health or other possible predisposing factors contributing to death, nor did the Vital Statistics indicate the instrument of death.

The county homicide and suicide rate data for both years were similar, and averaged to

obtain a single representative rate. The mean county homicide and suicide rates were then compared to drinking water and mean urine lithium levels and rainfall. The degree of mathematical significance of differences in homicide and suicide rates attributable to the ingestion and excretion of lithium as well as rainfall were ascertained by the Students "t" (Table VIII) and "r" analysis (Table IX).

Results

Measurements of lithium in drinking water and urine are listed in Table I along with the corresponding mean annual rainfall in each county. As there were not significant variations in the multiple lithium measurements of water from a single source, only one value per community is reported. The urine lithium levels are reported as: (1) the average urine measurements for the adult population of each county seat, (2) the range of individual measurements, (3) the number of adult subjects whose urine was included from each community. The data has been grouped according to drinking water lithium levels into four distinct groups of communities with incremental exposure to naturally occuring lithium. Comparisons of the water and urine lithium measurements and the amount of annual rainfall for both the individual communities and the four major groups of communities, reveals directional changes. As the annual rainfall increases, the lithium level in the drinking water and the lithium concentration in the urine of people who live in those communities progressively decreased.

Figure 1 is a line graph of drinking water lithium versus urine lithium levels. The first point is the average lithium urine level for the five communities with no measurable lithium in their drinking water. The second point represents the remaining six communities of the lowest ($\leqslant 11.0\ \mu g/L.$) water lithium group (see Table I). The remaining points in Figure 1 are the remaining group averages of Table I. This graph shows nearly a straight line relationship between water lithium concentration and lithium exretion when the water lithium intake was above 6.6 μg/Liter.

A significant decrease in admissions to state mental hospitals was apparent, as the community's intake of lithium is increased through its local water supply. A similar trend was observed in the rates for patients from these counties who were diagnosed as schizophrenics, other psychotics, neurotic, or with personality problems (see Table II). There is almost a four fold decrease in admission of these four categories of diagnoses with incremental water lithium exposure. A similar trend was not found when the admission for drug abuse, alcoholism, or mental retardation admissions were examined.

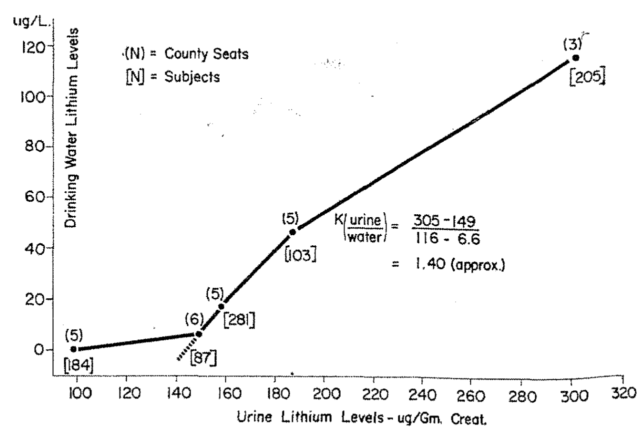

Fig. 1: Graph of drinking water lithium versus urine lithium levels.

TABLE I

Municipal Water and Urine Lithium Levels in 24 Texas County Seats With Mean Annual Rainfall.

County	Municipality	River Basin	Annual Rainfall (inches)	Water Lithium (ug/Liter)	Urine Lithium (ug/Gm. Creatinine) m (range) N
Lithium: <11.0 ug/Liter					
Dallas	Dallas	Trinity	35	0	63 (0-670) 52
Tarrant	Fort Worth	Trinity	31	0	108 (0-797) 39
Wichita	Wichita Falls	Red	28	0	98 (6-636) 39
Limestone	Groesbeck	Brazos	38	0	69 (0-597) 22
Guadalupe	Seguin	Guadalupe	31	0	154 (0-527) 32
Newton	Newton	Sabine	57	2	187 (22-822) 17
McLennan	Waco	Brazos	32	4	172 (15-500) 7
Anderson	Palestine	Trinity	41	6	107 (17-425) 27
Hardin	Silsbee	Neches	53	8	110 (7-736) 13
Travis	Austin	Colorado	33	10	101 (6-333) 20
Uvalde	Uvalde	Nueces	23	10	220 (11-548) 3
		means:	37	4	126(0-797) 271
Lithium: 11.0-29.9 ug/Liter					
Bexar	San Antonio	Guadalupe	28	11	116 (9-590) 88
Harris	Houston	San Jacinto	46	12	86 (0-444) 96
Washington	Brenham	Brazos	39	15	154 (5-714) 29
Frio	Pearsall	Nueces	23	22	294 (20-362) 21
Ector	Odessa	Colorado	14	25	138 (27-1000) 47
		means:	30	17	158 (0-1000) 281
Lithium: 30.0-69.9 ug/Liter					
Nueces	Corpus Christi	Nueces	28	33	209 (30-1075) 44
Jones	Anson	Brazos	23	38	187 (11-727) 20
Duval	San Diego	Nueces	23	50	112 (61-156) 6
Haskell	Haskell	Brazos	23	51	213 (77-1000) 16
San Patricio	Aransas Pass	Nueces	31	60	214 (19-509) 17
		means:	26	46	187 (11-1075) 103
Lithium: >70.0 ug/Liter					
Dimmit	Carrizo Springs	Nueces	21	79	197 (64-404) 33
El Paso	El Paso	Rio Grande	8	130	332 (12-1194) 114
Hidalgo	Weslaco	Rio Grande	19	139	386 (52-1433) 58
		means:	16	116	305 (12-1433) 205

TABLE II

State Mental Hospital Diagnostic Rates Per 10,000 for each County from Sept. 1, 1967 to Sept. 1, 1969 Arbitrarily Grouped According to Municipal Water Lithium Levels.

Lithium Groups County	(N)	Psychosis (A) Schizoid	Psychosis (B) Others	Neurosis (C)	Personality (D)	Combined (A+B+C+D)
<11.0 ug/liter	(11)					
Dallas		6.1	9.6	2.4	3.9	22.0
Tarrant		2.6	2.8	0.5	1.7	7.6
Wichita		5.3	7.5	2.9	10.6	26.2
Limestone		3.9	11.1	4.5	3.3	22.8
Guadalupe		4.7	5.6	1.6	3.1	14.9
Newton		3.5	4.8	1.9	12.4	22.5
McLennan		4.5	7.2	4.3	11.7	27.7
Anderson		4.6	13.3	4.2	8.4	30.5
Hardin		4.3	7.1	0.7	5.3	17.5
Travis		8.3	13.3	3.4	12.5	37.5
Uvalde		5.3	7.8	1.2	1.8	16.1
means:		4.8	8.2	2.5	6.8	22.3
11.0 - 29.9 ug/liter	(5)					
Bexar		3.9	5.1	1.1	4.1	14.2
Harris		4.3	6.5	1.8	5.2	17.7
Washington		3.9	12.4	3.2	1.6	21.2
Frio		2.2	4.7	0.9	3.8	16.3
Ector		4.0	4.8	1.9	7.4	18.1
means:		3.7	6.7	1.8	4.4	17.5
30.0 - 69.9 ug/liter	(4)					
Nueces		1.9	2.6	1.3	2.5	18.3
Jones		4.4	6.7	1.2	5.5	17.9
Duval		3.2	4.3	0.0	0.0	7.5
Haskell		1.9	2.3	2.3	2.3	8.8
San Patricio		3.1	3.8	1.8	5.0	13.7
means:		2.9	3.9	1.3	3.0	13.2
>70.0 ug/liter	(3)					
Dimmit		2.2	3.3	0.0	0.0	5.5
El Paso		1.8	2.6	0.4	1.2	5.1
Hidalgo		3.2	4.4	0.2	0.7	8.5
means:		2.4	3.4	0.2	0.6	6.3

TABLE III

Results of Students "t" Comparison Between Rates of Admissions and Diagnosis Grouped Below 11.0 μg/L, and Above 70.0 μg/L. Drinking Water Lithium.

Rates	Water Lithium <11	Water Lithium ≥70	"t"	P
N	11	3		
Admission:				
All	38.3 ± 5.4	12.3 ± 0.6*	4.78	≤.001[y]
First	18.9 ± 2.1	6.1 ± 0.8	5.55	≤.001
Secondary	19.4 ± 3.6	6.0 ± 0.3	3.78	≤.01
Diagnosis:				
Psychosis:				
Schiz.	4.8 ± 0.4	2.4 ± 0.4[z]	3.63	≤.01
Others	8.2 ± 1.0	3.4 ± 0.5	4.18	≤.01
Neurosis	2.5 ± 0.4	0.2 ± 0.1	5.85	≤.001
Personality	6.8 ± 1.3	0.6 ± 0.3	4.92	≤.001
Combined	22.3 ± 2.4	6.3 ± 1.2	5.79	≤.001
Urine Lithium, ug/Gm Creat.	126 ± 15	305 ± 69	2.59	≤.05
Annual Rainfall, inches	37 ± 1.6	16 ± 4.9	0.66	N.S.

*Mean ± SEM, Rates per 10,000 County Population
y Statistically Significant at P≤.05
z Mean ± SEM, Rates per 10,000 County Population

The levels of confidence resulting from the Students "t" comparisons of the mean admissions and diagnostic rates of the lowest versus the highest level of community drinking water lithium groups are presented in Table III. All observed differences in mean admission rates (all, first, and secondary), mean diagnostic categories for schizophrenics, other psychotics, neurotic, and personality problems and mean renal excretion of lithium were found to differ significantly with high levels of confidence ($P \leqslant .05$, $\leqslant .001$). Only the relationship to annual rainfall was not significant.

The diagnostic rates for schizophrenia, other psychoses, neurosis, and personality problems were grouped and analyzed within four incremental ranges of lithium excretion (Table IV). All of the diagnostic rates were progressively lower at each higher range of lithium excretion.

The confidence levels resulting from the Students "t" comparisons of the mean admission rates and mean disgnostic rates of the lowest versus the highest renal lithium excretion group (< 110 versus > 240 μg/Gm. Creatinine) are given in Table V. All differences proved statistifally significant ($p \leqslant .05$, $\leqslant .01$) except for relationship to water concentration and annual rainfall.

The confidence levels of the product-moment correlation studies are listed in Table VI. The drinking water lithium levels were significantly correlated inversely with each admission rate; each of the four diagnostic rates and positively with the urinary lithium correlation and annual rainfall ($p \leqslant .01$, $\leqslant .001$).

The urine lithium was inversely correlated at statistically significant levels with all and first admission rates; with psychotic and neurotic diagnostic rates, and with annual rainfall, ($p \leqslant .05$, $\leqslant .001$) and positively with water lithium level.

Annual rainfall was positively correlated with the county rate of first admission and all of the three effected diagnoses ($p \leqslant .05$, $\leqslant .02$). Rainfall was negatively correlated with water lithium levels ($p \leqslant .001$) and urine lithium levels ($p \leqslant .001$).

TABLE IV

*State Mental Hospital Diagnostic Rates * from Sept. 1, 1967 to Sept. 1, 1969 Grouped According to Mean Urine Lithium Level of the Resident County Seat.*

Urine Lithium ug/Gm. Creat.	County Seats N	Psychotic (A) Schiz ◆	Psychotic (B) Others	Neurotic (C)	Personality (D)	Combined (A+B+C+D)
<110	8	4.9 (2.6-8.3)	8.9 (2.8-13.3)	2.6 (0.5-4.5)	6.4 (1.7-12.5)	22.7 (7.6-37.5)
110 - 190	8	4.0 (3.2-4.7)	6.4 (4.3-12.4)	1.9 (0.0-4.3)	5.7 (0.0-12.4)	18.0 (7.5-27.7)
190 - 240	5	2.9 (1.9-5.3)	3.9 (2.3- 7.8)	1.3 (0.0-2.3)	2.3 (0.0- 5.0)	12.5 (5.5-18.3)
>240	3	2.4 (1.8-3.2)	3.9 (2.6- 4.7)	0.5 (0.2-0.9)	1.9 (0.7- 3.8)	9.9 (5.1-16.3)

*Mean (range) per 10,000 population

TABLE V

Results of Students "t" Comparison Between Rates of Admissions and Diagnosis Below 110 and Above 240 μg/Gm. Creatinine Urine Lithium Levels.

Rates	Urine Lithium, ug/Gm. Creat. <110	Urine Lithium, ug/Gm. Creat. >240	"t"	P
N	8	3		
Admission:				
All	40.4 + 7.8	15.4 + 4.3*	2.81	≤.05[y]
First	19.5 + 4.2	7.7 + 2.7	2.46	≤.05
Secondary	20.8 + 4.8	7.6 + 1.6	2.58	≤.05
Diagnosis:				
Psychosis				
Schiz ◆	4.9 + 0.6	2.4 + 0.5	3.24	≤.01
Others	8.9 + 1.4	3.9 + 0.8	4.00	≤.01
Neurosis	2.6 + 0.5	0.5 + 0.3	3.56	≤.01
Personality	6.4 + 1.4	1.9 + 1.1	2.50	≤.05
Combined	22.7 + 3.4	9.9 + 4.0	2.46	≤.05
Water Lithium, ug/L.	4.5 + 1.9	97.0 + 46.0	2.02	N.S.
Annual Rainfall, inches	38 + 8.0	17 + 5.4	2.21	N.S.

* Mean ± SEM, Rates per 10,000 County Population
z Mean ± SEM, Rates per 10,000 County Population
y Statistically significant at P ≤.05

Table VII lists the county homicide and suicide rates, calculated from the state Vital Statistics reports[27,28] grouped for comparison according to incremental exposure to drinking water lithium. An inverse quantitive relationship is apparent. A similar relationship between county homicide rates and lithium excretion was found. There appears to be a total 58% decrease in mean homicide rates from the lowest to the highest water lithium group and a 77% decrease in mean county homicide rates from the lowest to the highest lithium excretion group.

Table VIII itemizes the levels of confidence of the Students "t" test comparing the mean county homicide and suicide rates of the highest and lowest water lithium, urine lithium, and annual rainfall groups. The mean differences in homicide rates were significantly different in each comparison ($p \leqslant .01, \leqslant .001$), but the suicide rates were not.

Table IX presents the results of the product-moment correlation studies between the county homicide and suicide rates and the simultaneous measurements in drinking water lithium, urine lithium, and mean annual county rainfall. The homicide rates were found to be inversely correlated to drinking water lithium ($p \leqslant .02$); and urine lithium ($p \leqslant .01$); but positively correlated to annual rainfall ($p \leqslant .01$. The suicide rates were not correlateable at a confidence level of statistical significance with any of the three different measurements.

Discussion

The total rates of admission to State Mental Hospitals (all, first, and secondary) appear to be related to the water and urinary lithium levels. Of the 36,767 total admissions during the two year period (September 1, 1967 to September 1, 1969), 21,513 or 58% were for the diagnosis of schizophrenia, other psychoses, neurosis, and personality problems. Therefore, these four psychiatric problems contribute significantly to the patient population of the state mental hospitals. The greatest patient populations were contributed from counties with low lithium levels.

The results of several statistical analyses indicate that the incidence of homicide is lithium dependent, whereas the incidence of suicide is possibly linked to lithium. The incidence of both forms of murder (others and self) was obviously lowest in those counties with the highest level of lithium metabolism. According to the Vital Statistics[27,28] the average incidence per 10,000 people for the

entire state during these two years was 1.2 for homicide and 1.00 for suicide. The cumulative number of deaths due to both causes for the two years period totaled 4,916. This number is impressive and nearly equals the 4,934 deaths in Texas due to motor vehicle accidents for the same period. Certainly, further confirmatory studies of the epidemiological effects of lithium are indicated.

The state mental hospitals in Texas are located in Houston-100 beds, Harlingen-42 beds, Austin-2400 beds, Big Spring-900 beds, Kerrville-1450 beds, Rusk-2000 beds, San Antonio-2100 beds, Terrell-2610 beds, and Wichita Falls-1515 beds. It is a possibility that the admission rates to these mental hospitals may be influenced by the distance of the county seats from the mental hospitals. Patients residing a considerable distance from a state hospital may be hesitant to seek hospitalization far away from their home. On the other hand, staff personnel may be more likely to admit a patient residing a greater distance from the hospital than one residing within the community who might be treatable as an out-patient.

The product moment correlation ("r") was used to evaluate the influence of travel distance on the admission and lithium data. The distance; in miles, from each one's county seat to their nearest specific referral mental hospital was measured on the state road map (Table X). A travel distance of five miles was assigned to each of the four counties with a state mental hospital within the county seat. The results of the correlation studies of mileage with each of the following are as follows:

	"r"	P
All admissions	—.4708	⩽.02
First	—.3985	N.S.
Secondary	—.4924	⩽.02
Psychosis:		
Schizoid	—.5862	⩽.01
Others	—.6105	⩽.01
Neurosis	—.3197	N.S.
Personality	—.3169	N.S.
Combined	—.4081	N.S.
Water Lithium	+.4900	⩽.02
Urine Lithium	+.3682	N.S.
Rainfall	—.2522	N.S.

It would appear that distance exerts an influence on re-admissions to state mental hospitals and admissions due to psychosis. However, a correlation was also found between distance and drinking water lithium levels. In order to resolve this apparent consequence between distance to the mental hospital and drinking water lithium levels, the 11 counties having less than 11 μg/liter of lithium in their drinking water and the 13 counties with more lithium in the drinking water

TABLE VI

Results of Product Moment Correlation ("r") Studies Between Rates of Admission, Diagnosis and Rainfall, Lithium in Drinking Water and Urine ($N=24$).

	Water Lithium		Urine Lithium		Annual Rainfall	
	"r"	P	"r"	P	"r"	P
Admissions:						
All	- .5118	≤.01	- .4469	≤.05*	+ .3724	N.S.*
First	- .5130	≤.01	- .4365	≤.05	+ .4718	≤.02
Secondary	- .4609	≤.05	- .4112	N.S.	+ .2657	N.S.
Diagnosis:						
Psychosis:						
Schiz.	- .6009	≤.01	- .6118	≤.001	+ .5586	≤.01
Others	- .5526	≤.01	- .5518	≤.01	+ .4596	≤.05
Neurotic	- .6200	≤.001	- .5191	≤.01	+ .4538	≤.05
Personality	- .5064	≤.01	- .3208	N.S.	+ .4636	≤.02
Combined	- .6336	≤.001	- .5600	≤.01	+ .5103	≤.01
Water Lithium	+ 1.000	----	+ .7517	≤.001	- .6540	≤.001
Urine Lithium	+ .7517	≤.001	+ 1.0000	----	- .8032	≤.001
Annual Rainfall	- .6540	≤.001	- .8032	≤.001	+ 1.0000	----

Statistically Significant at P ≤ .05

are correlated separately.

When the water lithium level was below 11.0 μg/liter, travel distance negatively influenced the all admissions rates ($r = -.6057$, $p \leqslant .05$) and the secondary admission rates ($r = -.7194$, $p \leqslant .07$). The travel distance did not influence the first admission rates. Schizoid psychosis rates were inversely correlated to distance ($r = -.6402$, $p \leqslant .05$), but other psychoses, neurosis, and personality problems were not. When the water lithium level was above 11.0 μg/liter, travel distance did not significantly influence the admission rates (all, first, and secondary) or the diagnostic rates (both psychoses, neurosis, and personality problems). Thus, distance doesn't appear to be the explanation.

Conceivably, another factor influencing mental hospital admission is population density pressure (Table X). The Texas State Legislature usually approves construction of state hospitals in locations with urgent patient need, which is also apt to be the area with the highest population density. To evaluate the effect of population density on hospital admission, the product-moment correlation "r" was calculated for each county's population density (persons per square mile) versus each county's admission, diagnostic suicide, and homicide rates. No significant correlation was found between the county population densities and (1) county admission rates (all first, or second), (2) county diagnostic rates, or (3) county suicide rates.

However, as one might expect, a direct correlation of high statistical significance was found between county population density and homicide rates ($r = +.6699$, $p \leqslant .001$). This finding appears contrary to the negative correlation previously observed between county homicide rates and both drinking water and excretory lithium levels. Consequently, it was considered desirable to determine separately the degree of correlation between population density and homicide for those counties with

TABLE VII

Average County Homicide and Suicide Rates Per 10,000 for 1969, Grouped According To Drinking Water Lithium Levels.

County	Homicide	Suicide
<11.0 ug/Liter		
Dallas	1.99	1.13
Tarrant	1.64	1.27
Wichita	0.92	1.55
Limestone	1.11	1.11
Guadalupe	1.09	0.94
Newton	2.00	0.00
McLennan	1.08	1.15
Anderson	0.54	1.25
Hardin	0.71	0.17
Travis	1.17	0.93
Uvalde	0.31	2.18
means	1.14	1.06
11.0-29.9 ug/Liter		
Bexar	1.26	0.83
Harris	1.99	1.35
Washington	1.39	1.11
Frio	0.00	0.31
Ector	0.83	0.83
means	1.09	0.89
30.0-69.9 ug/Liter		
Nueces	0.67	1.10
Jones	0.31	1.25
Duvall	0.45	1.36
Haskell	0.62	1.25
San Patricio	0.79	0.34
means	0.57	1.06
≥70.0 ug/Liter		
Dimmit	0.56	0.56
El Paso	0.57	1.07
Hidalgo	0.31	0.37
means	0.48	0.67

TABLE VIII

Results of Students "t" Comparison Between Homicide and Suicide Rates of Extreme Lithium and Rainfall Groups.

Parameters	N	Homicide	Suicide
A. Water Lithium			
<11.0 ug/L.:	11	1.14+ 0.16	1.06+0.15
>70.0 ug/L.:	3	0.48+ 0.14	0.67+0.25
t		3.1429	1.3448
P		≤.01	N.S.
B. Urine Lithium			
<110 ug/Gm. Creat.:	8	1.26+0.19	1.10+0.08
>240 ug/Gm. Creat.:	3	0.29+0.20	0.67+0.81
t		3.5920	0.5308
P		≤.01	N.S.
C. Annual Rainfall			
<25 inches	9	0.44+0.08	1.02+0.12
>35 inches	7	1.39+0.16	0.87+0.07
t		6.7857	1.1538
P		≤.001	N.S.

drinking water lithium levels below 11.0 μg/liter and above 11.0 μg/liter lithium. The degree of correlation was also determined between population densities and mean urine lithium levels for these two groups.

The results of these two evaluations were very illuminating. The correlation between population density and homicide rates was similar for both the low lithium (r = + .6251, p ⩽ .05) and the higher lithium levels (r = + .7474, p ⩽ .01). Moreover, the high level of confidence for the correlation between homicide rates and population densities suggests that the influence of population density is more predictive than lithium metabolism on the homicide rates.

TABLE IX

Results of Product Moment Correlation "r" Studies Between Homicide and Suicide Rates and Lithium Levels, Rainfall.

	Homicide		Suicide	
	"r"	P	"r"	P
Drinking Water Lithium	-.4945	≤.02*	-.2354	N.S.
Urine Lithium	-.5858	≤.01	-.2585	N.S.
Rainfall	+.6141	≤.01	-.2669	N.S.

* Statistically Significant at P ≤.05

TABLE X

The Distance (in Miles) from County Seats To Referral State Mental Hospitals and County Population Densities (Persons Per Square Miles).

County Seat	Distance (miles)	Population Density (per Sq. mile)
Lithium: 110 ug/liter		
Dallas	32	1383
Ft. Worth	114	787
Wichita Falls	5*	180
Groesbeck	103	19
Sequin	34	45
Newton	116	11
Waco	104	139
Palestine	30	26
Silsbee	137	31
Austin	5*	270
Uvalde	75	10
means:	69	264
Lithium: 11.0-29.9 ug/liter		
San Antonio	5*	669
Houston	5*	950
Brenham	93	29
Pearsall	41	14
Odessa	51	99
means:	39	352
Lithium: 30.0-69.9 ug/liter		
Corpus Christi	156	255
Anson	105	17
San Diego	129	6
Haskell	95	7
Aransas Pass	139	65
means:	125	70
Lithium: >70.0 ug/liter		
Carrizo Springs	102	7
El Paso	343	324
Weslaco	25	114
means:	157	148

*Assigned distance to local state hospital

the homicide rates.

Even so, it is not possible to invalidate the effect of lithium metabolism on homicide. There are five counties in this study with water lithium levels below 11.0 μg/liter which are also characterized by population densities above 100 people per square mile (Dallas, Tarrant, Wichita, McLennon, and Travis). The average density of these five counties is 551 people per square mile and the average homicide rate is 1.36 per 10,000 population. In comparison, there are also five counties with drinking water lithium levels above 11.0 μg/liter (Bexar, Harris, Nueces, El Paso and Hidalgo) characterized by population densities above 100 people per square mile. The average density of these latter five counties is 462 people per square mile and the average homicide rate is 0.96 per 10,000 people. If population density alone was considered a factor in homicide rates, then by simple direct proportioning (551/462=1.36/x), a calculated average homicide rate for the latter five counties would be 1.13 per 10,000 people. This figure is 18 per cent above the actual average rate of 0.96 per 10,000 people, and the difference may be attributable to the direct effect of lithium metabolism.

The same comparisons hold valid for the remaining counties with lesser population densities. The average population density of the remaining six counties with water lithium levels below 11.0 μg/liter is 24 people per square mile with an average homicide rate of 0.96 per 10,000 people. There are eight counties with drinking water lithium levels above 11.0 μg/liter and characterized by population densities below 100 people per square mile. The average population density of this group of counties is 31 people per square mile and the average homicide rate is 0.62 per 10,000. Considering population density alone and predicting by direct proportion (24/31=

0.96/x), a calculated homicide rate of 1.24 per 10,000 people would be anticipated. However, the observed average rate of 0.62 homicides per 10,000 people is exactly one-half of the predictable rate of 1.24 homicides per 10,000 people, based on population density alone. This comparison indicates that lithium metabolism (intake and excretion) does exert a significant influence in direct opposition to the population density.

The number of beds in each of the state mental hospitals could be considered a mitigating factor in county admission rates. However, all of the nine hospitals are available without quota to residents of all 254 counties in the state with regard only to the individual needs of a patient. When a bed is needed, but not available in the nearest facility, another hospital is utilized. Therefore, an attempt to establish the influence of the number of near or far mental hospital beds on county admission rates is beyond the scope of this paper. Further, only 36% of the hospitalized mental patients are admitted to state institutions, the remaining 64% are admitted to psychiatric beds in hospitals operated by federal, municipal, general hospitals, psychiatric hospitals. Aside from the beds of these facilities, there are numerous out-patient phychiatric clinics and community mental health centers in the state which function in reducing admission to state mental hospitals.

The total population of the 24 study counties in 1968 was six million and constituted over 60 per cent of the total state population. This is a substantial group and while probably a minority of the hospitalized mentally ill within the state were admitted to state mental hospitals, all forms of mental illnesses were represented. Of all these represented, only the four diagnoses reported had a mathematical relationship to the lithium concentration in the water supply of the subjects place of residence.

These significant mathematical relationships between rates of (1) mental hospitals admission, (2) four categories of diagnoses, and (3) homicide rates and (1) water lithium levels, (2) urine lithium levels, and (3) annual rainfall levels provide three separate illustrations of the observed lithium relationship with mental illness and homicide.

Trace elements in drinking water have previously been shown to reflect in varying degrees the distribution of the elements in the rocks and soils as a whole.[29,30] Webb, et al, used this technique to detect hypocuprisis due to molybdenum toxicity in livestock.[31] The copper deficiency was confirmed by extremely low blood copper levels, even when overt clinical symptoms were not evident, and all animals responded to medication with copper by increased weight gain. The similarity between the copper study and our lithium report indicates that an optimal intake of water borne lithium may prevent some forms of mental illness.

Conclusion

A statistically significant mathematical relationship has been demonstrated between the drinking water content and the renal excretion of lithium in persons over 16 years of age. The lowest lithium levels in drinking water and urine occur in the northeast corner of Texas and increase progressively across the state to the highest levels in southwest Texas.

A quantitative relationship exists between both community lithium ingestion via tap water and excretion and both first and secondary county admission rates to state mental hospitals. This relationship includes those major forms of mental illness diagnosed, tabulated, and reported by the Texas Department of Mental Health and Mental Retardation as schizophrenia, psychosis, neurosis, and personality problems. In addition, county homicide rates were markedly reduced proportional with increasing lithium ingestion and excretion.

Apparently, water soluble lithium is present in the soil, predominantly in the western half of Texas. Varying with rainfall, such lithium is leached out of the soil and may be found in community drinking waters. Depending upon the quantity of lithium ingested, absorbed by the body, utilized by tissue cells and finally excreted; it would seem that the populace of any community should derive a prophylactic benefit with respect to the four

major forms of mental illness and to homicidal tendencies.

REFERENCES

1. Lewis, W. H. and Suris, O. R.: *Tex. Med.,* 66: 58-63, 1970.
2. Gershon, S.: *Dis. Nerv. Syst.,* 29:51-55, 1968.
3. Sheard, M.: *Nature,* (Lond.) 230:1134, 1971.
4. Ferrari, M.: *Osp. Psichiata,* 38:208-43, 1970.
5. Miller-Kuppers, M.: *Prox Kinderpsycol Kinderpsychiata,* 20:3-8, 1971.
6. Shal, S. A.: *Ment. Hyg.,* 53:21-33, 1969.
7. Owens, D.: *Curr. Psych. Ther.,* 10:179-81, 1971.
8. Guze, S. B., et al.: *Amer. J. Psychiat.,* 127: 832-5, 1970.
9. Cazanelli, A. et al.: *Amer. J. Phys.,* 135:309-315, 1942.
10. Krall, A. R.: *Life Sci.,* 6:1339-1344, 1967.
11. Kerry, R. J. and Owen, G.: *Arch. Gen.* Psychiat., 22:301-303, 1970.
12. Boer, L. et al.: *Arch. Gen. Psychiat.,* 22:108-113, 1970.
13. Foulks, J. et al.: *Am. J. Physiol.,* 1968:642, 1952.
14. Traufner, E. M. et al.: *Med. J. Aust.,* 42:28-291, 1955.
15. Dawson, et al.: *Dis. Nerv. Syst.,* 31:1-10, 1970.
16. Heier, K. S. and Billings, G. K.: "Handbook of Geochemistry", *Springer-Verlay,* New York 1970. p. 3-F-1.
17. Horstman, E. L., *Geochimica et Cosmochemica Acta.,* 12:1-28,1957.
18. Lowry, R. L.: Surface Water Resources of of Texas, *Texas Electrical Service Co.,* Nov., 1958.
19. McGanity, W. J., et al.: *Texas Medicine,* 65 (3):40, 1969.
20. Folin, O. and Wu, H.: *J. Biol. Chem.,* 38: 98-100, 1919.
21. Texas Dept. of Mental Health and Mental Retardation: *Patient Movement by County of Residency,* Sept. 1, 1967-Aug. 31, 1978. Austin, Texas. Table 3, pp. 27-35.
22. Texas Dept. of Mental Health and Mental Retardation: *Patient Movement by County of Residency,* Sept. 1, 1968-Aug. 31, 1969. Austin, Texas. Table 3, pp. 27-44.
23. U. S. Bureau of the Census, U. S. Census of Population: 1960, Vol., Characteristics of the Population, Part A, Number of Inhabitants, Washington, D. C.: *U. S. Govt. Printing Office,* 1961.
24. U. S. Bureau of the Census, U. S. Census of Population: 1970, Washington, D. C. *A Personal Communication.*
25. Stearns G.: *Ann. New York Acad.* Sc. 69:857, 1958.
26. Texas Almanac, 1970 Ed. *Dallas Morning News,* Dallas, Texas.
27. Texas State Department of Health: *Texas Vital Statistics,* 1968. Austin, Texas.
28. Texas State Department of Health: *Texas Vital Statistics,* 1969, Austin, Texas.
29. Webb, J. S., Fortescue, J., Nichol, I., and Tooms, J. S.: *Tech. Commun. Geochem. Prospect. Res. Cent.,* No. 47, 1964.
30. Nichol, I., James. L. D., and Viewing, K. A.: *Trans. Inst. Min. Mental,* 75:B 146, 1966.
31. Webb, J. S., Thornton, I. and Fletcher, K.: *Nature,* 217:1010-1012, 1968.