The Pigeon, a Sensor of Lead Pollution

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With increasing frequency it is realized that a variety of faunna and flora are sensitive biological indicators which reflect the severity of regional pollution of heavy metals (TANSY AND ROTH, 1970; GOODMAN AND ROBERTS, 1971; RAINS, 1971; MARTINEZ et al, 1971; BOWDEN AND McARTHUR, 1972). Though in the center part of Tokyo the controversial issue of lead poisoning attributable to the ambient atmoshpere which contains an increased level of lead has been raised recently (YAGYU et al, 1970; YAMADA, 1972), it is usually hard to find suitable moss or plants in the areas of heavy motor traffic. Pigeons, however, are ubiquitous in and around Tokyo Metropolitan area, inhabiting even the most densely populated areas with heavy traffic. With its small body size, high metabolic turnover, and rather limited mobility, a pigeon, as a biological indicator, is expected to demonstrate the severity of saturnine pollution at a given place more clearly than a man, whether the accumulation of the metal occurs per os or through the respiratory tract. In 1970, Tansy, reporting on a small number of pigeons, showed that there was a substantial increase in the lead content in the various organs of the ones living in Philadelphia.

A series of studies are being conducted by the Tokyo Metropolitan Research Laboratory of Public Health to assess if the pigeons can be a useful biological indicator of certain types of environmental pollutants. We now make an initial report on the measurement of lead concentrations of blood, femur and kidney, and those of δ-amino levulinic acid dehydratase activity (ALA-D) collected from the adult street pigeons in both downtown and suburban Tokyo.

METHODS AND MATERIALS

Total of 176 pigeons were caught at the 5 locations which were selected to cover the areas of from light to most heavy traffic (Table 1). The locations B and E are unique in that the pigeons living there are almost totally dependant on the feed provided by volunteers. Because of this reason the lead levels were determined with the contents in the crop of the pigeons and with the grains, water, sands and soil of the road surface of those two places in an attempt to assess which route makes the major contribution to the lead accumulation in the pigeons.

The blood lead level was measured only with those from which more than 6 ml of heparinized blood sample was

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TABLE I

Locations	Remarks	Lead content (µg/g)[0] Femur[#]	Kidney[#]	Blood Pb (µg/dl)	ALA-D activity (umolPBG/RBC/h)
Central Tokyo					
A Asakusa	Crowded temple, 100 m away from two main streets	31.6±16.0* n = 35	2.8±2.4* n = 37	33.0±20.4* n = 18	0.14±0.12* n = 38
B Shibuya	Bus terminal surrounded by main streets	24.8±20.9 n = 28	3.4±3.5 n = 23	32.8±13.8 n = 15	0.16±0.18 n = 20
C Gokokuji	Quiet temple, 50 m away from a main street	16.5±23.3 n = 47	1.7±2.8 n = 23	15.1±12.2 n = 15	0.18±0.09 n = 20
Suburban Tokyo					
D Tama	Quiet zoo in rural area	3.2±6.9 n = 47	0.8±1.1 n = 47	5.4±2.3 n = 20	0.58±0.18 n = 45
E Nakatomi	Farm house in rural area	2.0±3.0 n = 13	0.4±0.3 n = 13	2.9±3.0 n = 38	0.43±0.17 n = 35

0 : Measured only with those which were sacrificed
: Expressed on a wet basis
* : Mean ± S. D.

obtained with ease from the axillary veins and the analytical procedures followed those provided by Hessel (HESSEL, 1964).

After the birds were sacrificed by suffocation in an ether chamber, the organs were dissected and immediately frozen for preservation at minus 25C to minimize the loss of water content until the measurement was made.

The samples (organs, grains, soil, crop content) were dried at 120C to a constant weight and then converted to ash in an electric furnace at 500C over 16 hours. A sample was treated with 3.0 to 4.5 ml of 10 : 4 : 1 mixture of conc HNO_3, conc $HClO_4$ and conc H_2SO_4 and evaporated to a moist residue. This residue was leached with 50 ml of 1 N HCL and the insoluble matter (e. g. sand particles) was removed by centrifugation. The subsequent procedure was the standard dithizone -MIBK- atomic absorption spectrophotometric method (YAGYU et al, 1970).

The particles in the air were collected on a glass fiber filter (TOKYO - GB - 100R) with a low volume air sampler at each sampling location over a period of 8 hours (10:00 - 18:00) and aerosol Pb was measured as above quoted (HOMMA AND KOSHI, 1970; YAGYU et al, 1970). The ALA-D activity was obtained following the simplified method of Wada et al (WADA et al, 1970).

The amount of grain and water intake was assessed using 16 pigeons kept in separate cages, (average weight 355 g) over 12-day period. A polyvinyl container with a window was used to keep grains so that the loss due to messing was kept to minimal. Water loss due to evaporation was recorded with a control water bowl. In order to assess the amount of lead which was attached to the grains to be ingested by the pigeons, the grains provided at the locations B and E were scattered and retrieved with forceps from the ground at the feeding places on both a rainy day and a fine day.

RESULTS AND DISCUSSIONS

Figures 1 to 4 show the distributional differences of the parameters of the pigeons at those locations. Because of the skewed distribution, the data were normalized by logarithmic transformation. One-way analysis of variance demonstrates highly significant regional differences as to each parameter ($P \ll 0.01$).

The contrast between the places of heavy traffic and suburban areas is most clearly manifest in the lead concentration of the femur, blood and ALA-D activity. The tendency of lead to accumulate in the bones is known with

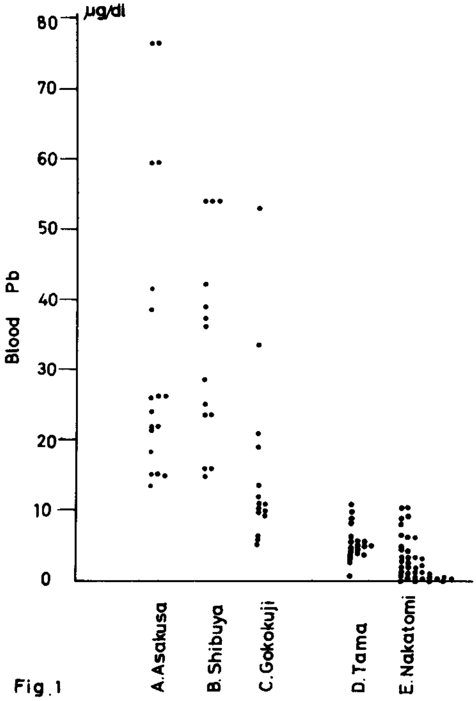

Fig.1

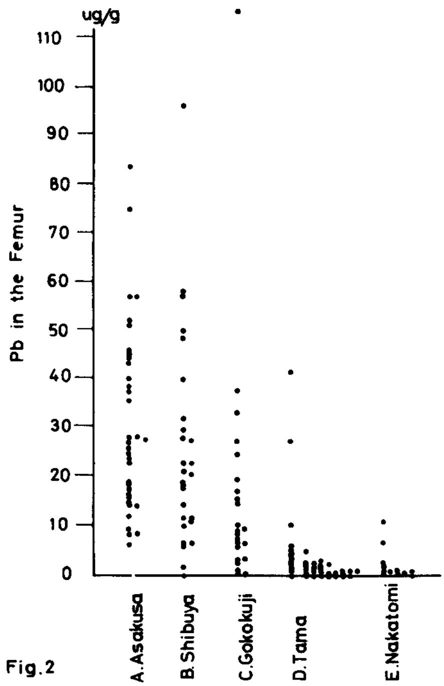

Fig.2

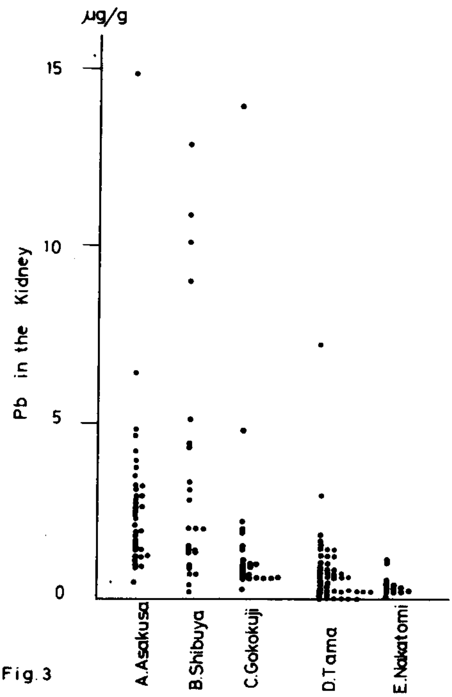

Fig.3

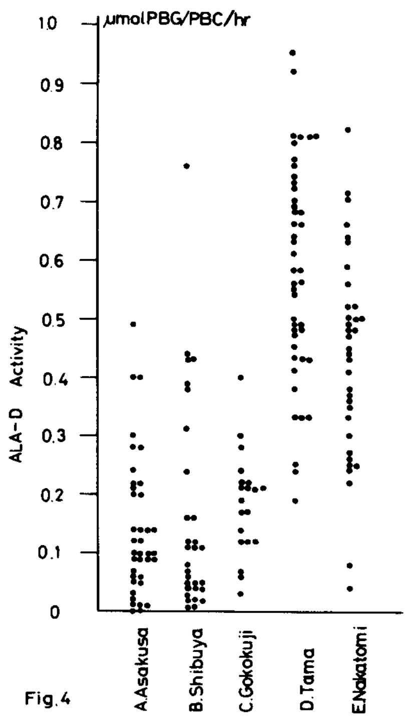

Fig.4

man (BARRY AND MOSSMAN, 1970) and similar mechanism can be operating in the pigeons. Two pigeons had blood levels over 75 ug/dl but none of them appeared any different in behaviour or constitution from other birds which had lower values.

The superb sensitivity of ALA-D activity as an indicator to the entrance of lead has been demonstrated and several researchers have stressed the close inverse association between the blood lead levels and ALA-D activities when an equilibrium is reached (de BRUIN AND HOOLBOOM, 1967; WADA AND YANO, 1968; HERNBERG et al, 1970). We also observed the presence of such an inverse relationship with pigeons as a whole (r : -0.6658, $P < 0.01$), though this was not the case within the individual groups. Whether ALA-D activity of RBC can be utilized as a reliable parameter of lead load in the pigeons clearly warrants further investigation. Once its place in diagnostic constellation is determined, one would expect this to be a most handy and least traumatic indicator: one has to sample only 0.2 ml venous blood from a pigeon and a trained technician can, at one time handling 20 samples, complete the analytical procedure in 3 hours.

We found that the grains retrieved from the ground with forceps had no increment of lead compared to the original feed. However, the greatly increased lead levels in the crop material of the pigeons at location B and the absence of the similar increase at location E indicate that the gizzard stones ingested at the former site are thickly coated with lead particles.

TABLE 2

Locations	Aerosol Pb (μg/m^3)	Lead Level of Crop Content (μg/g)	Lead Level of Feed* (μg/g)
Central Tokyo			
A Asakusa	0.35		grains: 0.14# n=25
B Shibuya	1.27	0.98# n=18	water : 0.54 n= 5
C Gokokuji	0.55		
Suburban Tokyo			
D Tama	0.16		grains: 0.12# n=3
E Nakatomi	0.20	0.08# n=12	water : 0.20 n=1

* : Grains were picked up after they had been scattered on the ground

: Mean

An average daily intake of grain and water observed with over 16 pigeons is 35 g and 28 ml. Based upon these data (Table 2) and the respiratory volume reported by Sturkie, the respective oral and respiratory lead intakes were calculated as 5.05 and 0.25 µg/day for the pigeons of location B and 4.25 and 0.05 µg/day for the pigeons of location E. The actual respiratory intake must be considerably higher than these figures which are based upon the observation made when pigeons were at supine position. Though the lead intake through the respiratory route at location B is five times greater than that at location E, it is premature to conclude that respiratory route plays a major role in bringing about the difference of lead concentration between the two groups of pigeons. Determination of the amount of lead through the respiratory and gastrointestinal tract awaits further studies.

CONCLUSION

Determination of lead levels of the blood, femur and kidney and δ-aminolevulinic acid dehydratase activity of red blood cells made with adult street pigeons (total of 179) of locations in both downtown and suburban Tokyo demonstrated highly significant regional differences. It appears that the street pigeons are a handy and sensitive indicator of regional satunine pollution.

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