Population density, personal distance and social distancing in the anthroposphere: Implications from the COVID-19 disaster

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Since the creation of organisms on the earth, the viruses have been concerning the mutations and evolutions of species, which selected multicellularity, gregariousness, and sociality as humans have. Infection at animal groups has extended viruses' possibility of survival, reproduction and evolution, which results in their coexistence with selected animal species including humans. In particular spatially varying environment with sufficient fresh (river and rain) water around the coastline makes various organisms survive. The coastal regions with biodiversity are suitable for fishery, agriculture and traffic for humans. Not viral but bacterial epidemics forced European to colonize Asian coastal regions and exploited their bioresources. The uneven distribution of human population is essential in the present pandemic, and should be studied also from earth-system and -environmental viewpoints.

We found out that the total cases (a sum of infected, recovered/deceased numbers) of COVID-19 in Japanese 47 prefectures, Indonesian 34 provinces, European 54 countries and US 55 states/territories are principally proportionate to the population density (see Figure), of which the inverse square root corresponds to "mean personal distance" (MPD). For the whole humans over the global land, MPD is (7.7 billion/150 million km^2)$^{-1/2}$ ≈140 m, which is similar to an Indonesian peatland. However, Asian megacities such as Tokyo (12 m) and Jakarta (8 m) have a very short MPD, which is only a few times of so-called social (or physical) distance (1~2 m) for contagious infections. This infection process is similar to aerosol/cloud formation, which should be studied by biometeorology or environmental medicine.

The proportionality factor increases gradually up to ~1 km^2 corresponding to an area where everyone would be eventually infected. The value is somewhat larger in Indonesia than in Japan, and seems to be much larger (~10^2 km^2) for the states of US. In Europe smaller countries (< 100,000 km^2) are similar to US, while larger countries (Italy, Spain, France, UK, Germany and Russia) are far larger than the common regression line. Variabilities are due to possible evolutions of virus, medical collapse, number of test, shopping area of necessities, and so on. These features are not inconsistent with an important fact that only 20% super-spreaders are responsible for transmission.

The SIR model predicting the infection for closed ('lockdown') people does not concern the spatial size, and its nonlinear governing equations do not yield a simple solution (I + R) for the final number of infected people. This study provides the final size experimentally, and accumulations of similar studies should improve the model and our understanding of pandemic infection processes.

The implications of "social distancing" techniques for sustainability are discussed on the population-area diagram. The risk of megacity due to its broadness without empty spaces should be suppressed by reconstruction of urban functions with a "towner social distance" around 1 km. Otherwise decentralization such as in Tokugawa Japan, which led development of industries and human resources, should be reestablished with the modern computer network. These strategies may contribute to general disaster prevention.

Figure. Total cases (= infected + recovered + deceased) of COVID-19 in (a) Japanese 47 prefectures, (b) Indonesian 34 provinces, (c) US 55 states (+ district = territories) and (d) European 54 countries (classified by WHO) every day during March 18-31 (violet), April 1-30 (blue) and May 1-31 (green), plotted in terms of "mean personal distance" (MPD, defined by the inverse square root of population density) on log-log diagrams. A slant dashed line indicates a -2 power law of MPD (that is, a proportionality to the population density), and shifts upwards/downwards with increasing/decreasing the area where everybody infected.

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