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Sciences of Complexity and Chaos to Analyze Vectors and Zoonosis

Emilio Arch-Tirado and Alfonso Alfaro-Rodríguez

*Instituto Nacional de Rehabilitación,
Laboratorio de Bioacústica, Mexico D.F.
Mexico*

1. Introduction

In the late 1960s and early 1970s of the recently past century were consolidated the Sciences of complexity and chaos¹. Complexity seems to follow a path through which the primary energy was transformed into particles, particles were amended and a force converted into atoms, molecules and atoms in molecules is polymerized into complex structures that are self-replication . There seems to also be a tangential force that includes information and knowledge².

On the other hand, chaos can be deterministic and non-deterministic. The first can predict their behavior although it can not be inferred, i.e., the number of external variables that infer it makes it almost impossible to manipulate, but you can know what will be the final behavior of the system. Likewise, we have the not deterministic, in that, as its name indicates it, the direction to take the system cannot be predicted, or the short life of human beings will not reach to analyse the final behavior of the system³.

Dynamic systems are complex systems of elements which interact not only with the elements in the system, but also relations among them. It is known that some systems operate in a linear fashion that its action can be predicted by the information relating to its point of starting and its rules of operation. Many systems apparently deterministic can be regulated or extremely unpredictable. The chaos theory, to put it in some way, with two branches, the first emphasizes the hidden order that exists in a system called chaotic system; the second branch refers to the process of self-regulation and self-control spontaneous⁴.

Lorenz contribution to knowledge of complex systems and the condition that can be chaotic is very important; Lorenz discovered, among other things, the fundamental characteristics of the systems that help us better understand what is known as chaos; Likewise, described the so-called Strange Attractors, which is popularly exemplify as "the butterfly effect", which refers to how a minimal variation in the initial conditions of a system can result in a totally unexpected effect, which would be equivalent to the idea of the "flutter of this insect in the Amazon could produce a storm a month later in Chicago". Lorenz contribution to knowledge of complex systems and the condition that can be chaotic is very important;

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Bioterrorism is defined as the release or use of any microorganism, virus, infectious substance or biological product that may be modified as a result of biotechnology, natural or by components of bioengineering in any microorganism, virus, infectious substance, or biological product that can cause death, disease or disability in people, animals, plants or other living organisms^{7,8,9} intentional. This paper aims to discuss and analyse the role of chaos in the proliferation of vectors and zoonosis induced and stochastic processes. The father of the linearity is Issac Newton; in its third Act set out that "every action has a reaction of the same magnitude but in the opposite direction", meaning a cause for effect. It is said that chaos theory breaks the paradigm of the linearity and Newtonian physics¹⁰.

One of the basic foundations in the theory of chaos is that many independent variables affect a single dependent variable, i.e. many causes for a single effect^{11, 12}. In chaotic systems the large number of independent variables present makes impossible their manipulation for what are complex processes. Given that all complex systems behave the same way, these concepts can be applied to health sciences. In this paper we propose the tools of the Sciences of complexity and chaos as a tool for the analysis of the proliferation of vectors and zoonosis in their potential use in bioterrorism.

There are about 400 type viral zoonoses in the world, in addition to numerous bacterial zoonoses. Likewise emerging diseases, approximately 75% are zoonotic¹³. 1,415 Species of infectious organisms known as pathogens for humans, these were reported in 2001, 61% are zoonotic origin, similar to 75% of 175 considered pathogens as emerging.

Zoonoses can be introduced naturally or involuntarily (travel international, smuggling of goods, and animals) or by means of biological weapons. Zoonotic agents can be considered for their release or intentional introduction to cause damage and confusion that can run at the same time affect the health of animals and human having a serious socio-economic impact. On the other hand in a report published in the Journal of the American Medical Association concluded that 80% of common and likely to be used in biological warfare pathogens are zoonotic agents^{7,14}.

One of the important concepts in dynamical systems is "that small changes in initial conditions of the system can generate major changes in the final result", but in the surface forms of its evolution is likely to take different routes, such as self-organization, synchronization, no predictability of the effects of small changes in initial conditions and the existence of simplicity of some levels while chaos exists in other forms in the fundamental concepts of complexity¹⁵.

Various properties spatiotemporal in complex systems emerge spontaneously from the interactions that occur in the system in question, which have an impact in a longitudinal manner over time, generating properties or unexpected effects in a given system; generating properties or unexpected effects in a given system; These properties has been called emergent processes. For example: it is known that when there is an overpopulation of a colony of lemmings, it enters into collective stress, then turns in droves to a cliff which precipitate. When the colony reaches a certain number you are calm and return to its territory. In this way, the colony regulates itself its population density. Complex systems can be critical systems characterized by the presence of spatiotemporals fluctuations in all possible scales existing in the system. It is important to mention that this phenomenon can be spontaneously and without the intervention of factors and forces external to the system, which is defined as self-organization. In many pathological processes in a particular community of animals, it is known that not all affected members will die; immunological properties of some is self-regulate and will compensate for the effects of the infectious agent¹⁶.

Strange Attractors, not static or periodic, under the same conditions may diverge in a short period of time, making the system one chaotic and unpredictable ¹⁷, for example: the interaction between variables determines the transmission of infections in populations that are often complex and nonlinear, likewise involved individual life styles, which can only be understood in historical contextcultural and social in which occur. On zoonoses, daily living with pets or farm animals vary from family family ^{18,19} and ²⁰ family economic status, so the flow of the spread can vary between each of these; Thus, with two equal systems at initial stage of a particular infectious disease will be different behaviors in its final phase. Strange Attractors, not static or periodic, under the same conditions may diverge in a short period of time, making the system one chaotic and unpredictable ¹⁷, for example: the interaction between variables determines the transmission of infections in populations that are often complex and nonlinear, likewise involved individual life styles, which can only be understood in historical contextcultural and social in which occur. On zoonoses, daily living with pets or farm animals can vary from family to family ^{18,19} and family economic status²⁰, so the flow of the spread can vary between each of these; Thus, with two equal systems at initial stage of a particular infectious disease will be different behaviors in its final phase.

There is ample evidence on the use of animals for early warning of a bioterrorist attack, has been observed that certain bioterrorism agents for, pets or livestock may prevent early, probably before manifested symptoms of the disease in humans to be detected in animals. Populations of animals such as wild birds, trade and shipping of livestock, as well as domestic animals involved in the local market or international trade could play a role in the maintenance and spread of an epidemic that is attributable to the deliberate release of a biological agent ^{7,14}.

In the case of avian influenza virus H5N1 has been reported that direct contact with poultry is to be a major cause of infection in humans. Taking the initial changes in the same system, such as the time and the type of daily living with this species, the contagion will have different evolution. It is known that in many developing countries, as it is the case of Latin America, some families have animals in backyard; Thus customs in each household care and

handling of the animals may differ, so a potential contagion and its dissemination will take different behaviors between different families²¹.

The Center for prevention and Disease Control (CDC) classifies agents and bioterrorism in categories A, B and C diseases, placing with the letter A, to those with highest priority since they represent a national security risk already because, a) can be easily disseminated or transmitted from person to person, b) result in high mortality rates and have the potential to impact on public health, c) could cause panic among the population and social disorders and, d) require special public health measures. The main actors are anthrax, botulinum toxin, plague, smallpox, tularemia, and hemorrhagic fever viral. However, in addition to those already mentioned, there are other offensive players as it is the case of brucellosis, glanders, Hendra virus, avian flu, Nipah virus, avian psittacosis, Rift Valley fever, melioidosis, cryptosporidiosis, Cryptococcosis, Q fever, fever of dengue, smallpox, equine viral encephalitis and viral hemorrhagic fevers which have been detected in animals other than smallpox and dengue fever^{7,14, 22}.

The majority of biological agents (especially of the type A) are effectively used spray; aerosols are the method most commonly used in a potential bioterrorism attack because they are the most effective means for wide dissemination⁷.

Returning to the case of the H5N1 avian influenza, the modification of a variable, such as slight variations of the migratory routes, can generate completely different results, so that the follow-up to the transmission of avian influenza is complex²³. We know that there are three clearly different States for the transmission of a zoonosis: excretion, presence in the environment and the entrance to the new host. Similarly there are two transmission mechanisms: caused by a vector and direct pollution from animal body fluids²⁴. Another complex factor in the analysis and monitoring of a possible source of infection is the incubation period, as this can vary between the different subjects²⁵. It is important to mention that many elements can contribute to emerge new zoonotic diseases of viral, or microbiological origin such as mutations, natural selection, progression would evolve, individual determinants of guests, acquisition of immunity, physiological determinants of the population of the host, behaviors, social characteristics of the guests, commercial transport, iatrogenic factors, ecological and climatic influences. Such is the case of the virus of swine influenza H1N1, cause of respiratory disease of pigs and that now their mutations have caused infection among humans^{26, 27}. It is known that the H5N1 virus, which has been isolated in more than 90 bird species in wildlife, mainly ducks, geese and 49 species of shorebirds, has been able to cross the species barrier and has given rise to many human cases of influenza avian; some research studies report a fatality from 80%. Coupled with this is has isolated the virus in feces of cats that ate dead birds, so it is likely that these animals are also potential carriers^{13,28,29,30,31,32}. The sum of these factors, in addition to migration routes and family customs, can give a chaotic model, making the analysis and follow-up of the epizootiology of influenza avian with conventional statistical tools³³. It is important to mention that migratory birds may be reservoirs or mechanical vectors of numerous infectious agents with respect to a possible transmission of diseases from birds to humans³⁴. Today it is known that many migratory birds have diverted their initial destinations and endings, as it has happened in the Lake of Guadalupe in Atizapan, State Mexico, where they currently live different kinds of

migratory birds which have become the fauna of the place. New methods of study have been adapted to the increase in infectious diseases, using models of Bayesian analysis, theories of social, technical networks of systems posnormales, which generated an increase of the different variables affecting the study population, the biology of the multiple hosts in infectious complexes and social and ecological systems³⁵.

2. Usefulness of fractals in the theory of chaos

In nature there are countless formed whimsical figures to the length of time for the random sum of all its parts, so we could ask ourselves: when in nature is a completely spherical River stone or a hexagonal-shaped volcanic stone or a grotto with a cathedral-like vaults?²³. It is obvious that man has simplified the capricious forms of nature in perfect geometric figures, starting from the basis for Euclidean geometry used today.

Based on the analysis of the figures of nature comes a new concept of these forms called "Fractals" by Mandelbrot³⁶. Fractals have the characteristic that they may represent something more than a line and less than a plane can be larger than a one-dimensional form and lower than a two-dimensional¹. The fractal depends on the scale of which is measured, so that the complexity of the forms and structures of nature are not accidental. Fractals can help to understand behaviors in different areas, from the distribution of galaxies in the universe until the spread of infectious diseases²³, to describe the formation of these random structures but with a certain pattern. For example, to observe the Gulf of Mexico from a satellite shown in the form of a semicircle, but approaching increasingly may distinguish forms that could not discriminate at the height of the satellite: large number of structures not symmetrical as bays, beaches, cliffs, stone, etc; When more detail will find more specific formations that break with the initial figure that would be the half circle. Another example would be the flower of broccoli; to the analyse in fragments increasingly smaller find structures similar to the original flower, which to the join form this, that, as mentioned, has a characteristic form, however, are not equal each other, share similar but not identical ways. A last example: the snow form irregular accumulations resulting in certain places be larger than others, in this way all clusters of snow are irregular and capriciously formed. Similarly, the grouping of cases in a particular epidemic could follow the trend groups in certain areas or regions. Based on this concept will be the utility of fractal geometry in epidemiology. Regarding social behavior in humans, we can say that some of them are still patterns of fractal formations, such as irregular settlements, where there is no defined order of the planning of streets and houses.

If he is a graph of dispersion of times and movements of the spread of a particular disease, we should possibly corresponding to fractal structures; in the graph, at each point you could see a new outbreak of the disease, for example: in a transmission of leptospirosis³⁷ by water contaminated in a given municipality, not concentrate the outbreaks of the disease near the source of the contaminated water, but in places where turned the carriers of the disease, either their homes or their sources of employment, which should be combined with the displacement of rats infected to places where the water stored for drinking contaminarian. Another example of spread of disease with this pattern would be that occurred at the beginning of the 20th century when the plague caused by *Yersinia pestis* killed millions of people to the Lake around the world³⁸, It is

known that this bacteria infects small mammals, especially rodents and is transmitted to humans by fleas. It has identified more than 200 different mammals and about 80 different species of fleas in the prevalence of this disease; the flea in rat *Xenopsylla cheopis* is considered the most competent vector³⁹. The chaotic spread was due to the displacement of the rats; If there will be a dispersion of times and movements of this spread chart we would possibly find a fractal formation. This type of graphics will give more information and understanding about the movement and spread of disease. The complexity of the swine influenza virus H1N1 is in their primary forms of infection, mainly people who have direct contact with these animals ^{27,40}; special cases like infection reported by a freshly dead animal viscera⁴¹, the subtypes due to mutations of the virus⁴², the first reports of infection between human⁴³, the resistance of the antiviral oseltamivir⁴⁴. Uniting these factors, the threat of a pandemic is latent⁴⁵ because these factors are fundamental in viral diseases emerging, probably generating structures similar to fractals to analyse the cases that are registered to the length of the epidemic. This happened in Mexico during the recent outbreak by the subtype of the virus H1N1, appointed by the World Health Organization on April 30, 2009 as AH1N1 influenza virus human (to curb the indiscriminate slaughter of the pig), because this subtype spread from human to human. If he is a graph of regional States and municipalities, possibly it would be up to fractal structures, which could understand behavior following cases in its transmission.

Finally, we can mention the fractal geometry can be a useful tool for analyzing the chaotic systems ²³.

3. Small world and social networks

Many times we have heard the phrase what little is the world!, mainly when two people are in a particular place and without knowing they have an acquaintance in common, resulting in the phrase "how small is the world". Societies, organizations and individuals are structured as a network of networks, interacting entities, who form "self-organized influence the quality and performance of their organizations"; self-organization is present in all of nature. The phenomenon of "small world" inherent in complex networks, shows that pooling is great but the distance from characteristic interconnection is very low. As a result, such networks are located in the complex area, between the total order and random. The "small world" phenomenon gives networks characteristics of optimization, such as computer and epidemiological flows: It is therefore essential to know in detail the social networks for phenomena that involve aspects of communication.

The usefulness of the small world on social networks implies that each of us are responsible for a given mode, where from, first, our relatives, friends and acquaintances, in turn each of them also has its node, so for them the primary node is for us our secondary node and so on. Using social networks in the analysis and monitoring of the spread of a disease, and its dissemination, displacements and the resulting direct contacts of relations that is daily with family, friends, coworkers and acquaintances may analyse more objectively. It is worth mentioning in addition to interpersonal relationships, long distances that are run on a daily basis make more complex this follow-up, for example: the inhabitants of big cities, as the case of the conurbados municipalities in the city of Mexico where people on average move approximately 20 Km or more to their places of

work. Globalization implies that many people in the morning respondents in their hometown and eat or cenen in a city or country. According to airports and auxiliary services of Mexico, 2008 attended 28 million passengers in airports in Mexico⁴⁶, so the number of passengers who travel around the world by week is million; in this way, the infection of a disease can spread rapidly around the world; possibly a detailed analysis of aviation networks could be the cornerstone for the monitoring of the spread of disease ⁴⁷. For example: it is common that some businessmen in the morning are closing a business in any city of United States and in the afternoon are having dinner at his home in Mexico; determinant can occur with the migration with the theory of small world and the spread of diseases, we have as a result the complexity for the analysis and monitoring of a certain disease, mainly of the undocumented ^{48,49}.

On the basis of the above examples by associating them; in the case of the zoonoses, little legislation in countries under development path, coupled with the little attachment is on the rules of transfer, the management of animal farm, which also affect the magnitude of the movements, and company result of commercial treaties between countries⁵⁰.

The existence of pet stores which allows children to interact with animals such as sheep, goats, cats, dogs and birds, without minimum hygiene conditions, both for animals and humans, with the potential risk of transmission of *Escherichia coli*⁵¹, in addition to this, the almost non-existent participation of veterinary clinics in terms of education for the health of their clients ^{52,53}, as well as the shortcomings of professional supervision of products of animal origin, can produce a complex spread of a particular zoonosis, in which disease appears at various points away from each other but with the same focus of origin. We know that *Brucella melitensis* mainly affects goats, but can also affect cattle and pigs; on the other hand, the *Brucella abortus* is the primary responsibility for the bovine brucellosis. *Brucella* is excreted in the milk and vaginal excretions in high quantities, even in asymptomatic cases.

In humans, as well as direct contact with infected animals, you can purchase to consume dairy products, coupled with the variability of the trade routes that are complex, so it is almost impossible to know the source of original contamination^{54,55}. Use the principles of "small world" and thorough analysis of the monitoring of relations between the different nodes (primary, secondary, tertiary, etc) of infected consumers, will be critical to understand the spread of this disease.

4. Usefulness of the analysis of processes of chaotic time series

The deterministic equations are structured to address a small number of variables, such form can ask few behaviors observed in nature describe deterministic equations with a small number of variables; on the contrary, the number of variables involved is high. To estimate the size of the strange attractors are useful time series, as they are generated by systems with many degrees of freedom ⁵⁶. There are many tools to analyze complex systems, in this article we will focus basically to time series for its ease of handling and understanding. A time series or chronological is a set of data recorded or observed in equal times; the purpose is to get a concise description of a series in particular, the construction of a model to explain the behavior of a series of time with respect to its history, or define a structure of behavior, i.e.

to establish a function of transfer and ultimately predict based on the results of the previous points⁵⁷. In this way, time series are used to analyze the behavior of certain variable over time, so that its fundamental measurement are variables temporary, analyzing its influence on the trend, seasonality and cyclical fluctuations and irregular variations, the latter being the possible generators of chaotic models. It is worth noting that a chaotic process can not manipulate independent variables that affect the process but we know the effect generated by them; Thus the end of the system effect, is known to carry out a thorough analysis of the behavior of the different variables affecting the final outcome.

When you want to analyze the behavior of certain variable over time, usually we carry out analysis according to months, quarters or years, and on many occasions there are variables that to be averaged over the month, quarter or year are smoothed (when estimated an average between a lot of data there is a risk of that extreme values do not significantly alter the standard deviation) with respect to all data obtained during the period being analyzed.

Temporal analysis, the period to analyze is the smallest possible, i.e. in days, given that one of the characteristics of chaotic processes is that "small changes that can be generated in the initial conditions generate totally unexpected results". In this way, to analyse increasingly shorter periods daily behavior of the process, identified the modifier variables and changes that will generate these throughout the study period; may examine on many occasions when you have not expected natural events or the uncontrolled spread of a given pathology, or mutations in different pathogens adapting to various changes in the environment, it is difficult to predict their behaviour⁵⁸. Investigate similar problems and describe the different scenarios where previous experiences known biases that occurred in the previous process, serves as background to generate campaigns of prevention or education for health in specific populations, for example: If in a certain area southeast of the Mexican Republic increases the amount of expected rain, may increase the population of *hemipteran insects*, sucking, as we know are responsible of transmitting *trypanosomiasis*, caused by the flagellate Protozoan *Trypanosoma cruzi*⁵⁹, Similarly, we know that the dog is the most important reservoir and found that it increases the risk of domestic transmission. If the increase in the population of dogs in the area add to the previous scheme, are not expected on the historical results. To use the analysis of time series include behavior that took the spread of Chagas disease in this area, is this way, certain actions will be taken. Another example would be the contamination of drinking water after a natural disaster: taking again as an example leptospirosis, where rodents dump large amount of *Leptospira* through urine, and transmission can occur through the skin and the mucous membranes to have direct contact with damp soil or vegetation contaminated, can be summarized that floods facilitated the proliferation of vectors, in association with the common proximity of rodents with humans⁶⁰. Analysing the behaviour of the effects of this disease in a given population at the end of a month, the data that would would casuistry. Analysing shaped retrospective per day, the behavior of the spread of this disease correlating cases obtained by day by variable, such as dissemination, climate change, relocation of the population, and so on, the behavior of this zoonosis; will better understand Thus, predictability will only be possible when analysing short periods, mainly on models with dynamic and unpredictable behaviour^{61,62}.

5. Discussion

The variety of emerging diseases that are detected by the day make us reflect on the role of biological vectors as well as the transmission goes with coexistence with animals. Likewise, as mentioned in the text a percentage of emerging diseases are zoonotic origin. Diseases of high pathogenicity as the case of the H5N1 influenza avian in the reported a mortality rate above 65% coupled with cultural and social elements mainly in developing countries increases a potential direct transmission by the coexistence or possible bad cooking meat consumption, if we add this to the diversity of migratory routes as well as alternate routes derived from attractors a pandemic would be the result the sum of these factors. Genetic engineering has played a key role in what is the manipulation of the genetic engineering of several species, creating uncertainty and social dissatisfaction with regard to unexpected infections; If we add the elements you just mentioned with an intentional inoculation can generate incalculable catastrophes, which is why health teams should be prepared using tools such is the case of stochastic processes and chaos to analyse possible routes and modes of transmission of any zoonotic disease, medicine has tried to divorce of physics We must break the paradigm of the linearity and study, understand and analyze the role of complex systems in the transmission of diseases. The change or modification of the independent variables accelerates and slows the discontinuity thresholds, thus the thresholds indicated various endogenous processes or positive feedback, and these proportions you rulers of the change.

Two isolated chaotic systems can not be synchronized, because although they are particularly identical and begin to function at the same time, immediately their lower case differences will be amplified and this will increasingly be more divergent among themselves, similar to two outbreaks of a given disease in two different places. Hence the importance of the use of time series, that modifier effect on space and time variables may be known to decompose the system into smaller periods.

Human populations have a high degree of connectivity, addition to the increase in connections for ease of travel, hence the approach of the "small world", which makes us think about the increase in the likelihood of a pandemic^{63,64}.

The variables that should be considered in a complex dynamic model are susceptibility, exposure, infection, immunity, clinical manifestations, incubation period, in some cases healthy carriers and travel, among others⁶⁵.

It is important to emphasis that dynamic systems are independent, in particular the incidence of a particular disease, since this is a direct consequence of susceptibility. Thus, the incidence of certain zoonoses, starting simulators where deemed mobilizations, risk and possible susceptibility of individuals of the study population must analyze. Regardless of the understanding or not of a dynamic process, the use of time for analysis series serves to study the behavior of a particular infection in a subject, subgroup or a particular population, likewise gives the opportunity to use smaller periods of time⁶⁶.

We reiterate that there are many tools to analyze complex systems, such as the Scale-Free Model Barabasi-Albert, among others; in this work have exemplified time series for easy understanding and handling for the analysis of non-linear systems, because they are useful

for interpreting and monitoring of a particular epidemic compared to linear models, for example: the trend of cases of a disease in particular is not linear over the year; they can identify cyclical fluctuations with respect to the seasons of the year, but this cyclical fluctuations will ever have identical behavior to analyze year by year, by which one may speak strictly of seasonality, that to ensure this, that you will need to have identical number of cases over the previous month year; so, irregular variations during the year of the cases of certain pathology will be the time series to analyze if it is possible to avoid the suavizamiento of data averaged over long periods of time in days. Finally, we believe that it is very important to know, disseminate and use the tools of the Sciences of complexity and chaos, as they represent a new paradigm that implies an advance to understand the dynamic processes of the biological and social phenomena.

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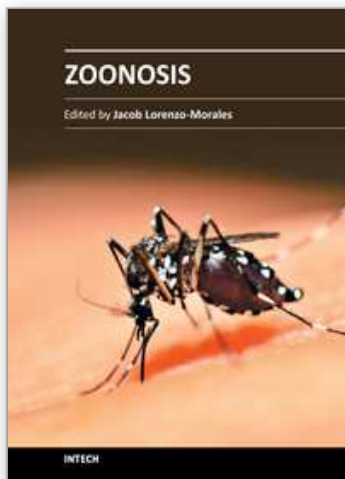
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Zoonotic diseases are mainly caused by bacterial, viral or parasitic agents although "unconventional agents" such as prions could also be involved in causing zoonotic diseases. Many of the zoonotic diseases are a public health concern but also affect the production of food of animal origin thus they could cause problems in international trade of animal-origin goods. A major factor contributing to the emergence of new zoonotic pathogens in human populations is increased contact between humans and animals. This book provides an insight on zoonosis and both authors and the editor hope that the work compiled in it would help to raise awareness and interest in this field. It should also help researchers, clinicians and other readers in their research and clinical usage.

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Slavka Krautzeka 83/A
51000 Rijeka, Croatia
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Unit 405, Office Block, Hotel Equatorial Shanghai
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Phone: +86-21-62489820
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