The effect and accumulation of antibiotics and their residues in horticultural plants: a review

Az antibiotikumok és maradékanyagaik hatása és akkumulálódása kertészeti növényekben: áttekintés

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Abstract

Antibiotics have been used in the agriculture in large quantities since they were discovered. In animal husbandry these compounds are used not only to do treatments for sick animals but for prevention of diseases and also for growth promotion. The extreme use of these antibiotics led to increasing numbers of antibiotic resistant bacteria. Today it is a danger that might be considered very seriously worldwide. In the European Union, the application of antibiotics as growth promoters is permitted since 2006. However, it is also known, from statistical data, that there are big differences in antibiotics use among the EU countries. The antibiotics that are applied in animal husbandry go to the arable fields through the manure application. From the soils crops and agricultural plants might take them and absorb, accumulate into their own tissues. There are only few studies demonstrating the harmful effects of antibiotics in humans or animals, however, several experiments were conducted to prove the deleterious effects of antibiotics in plants. The aim of this study was to explore the effect of antibiotics and their residues in horticultural plants. The consumption of the raw or processed vegetables with the accumulated antibiotics and their metabolites may result high risk on human health. The results of studies in this subject showed that the use of antibiotics must be continuously controlled in both human and animal applications. There is a necessity to inform of farmers (whom are producing and using manure on their fields) about the dangers and risks of over exposed antibiotics in the soil-plant-animal human food chain.

Keywords: antibiotics, antibiotics resistance, horticultural plants, manure, vegetable

Összefoglalás

Az antibiotikumokat felfedezésük óta nagy mennyiségben használják az állattenyésztési ágazatban nem csupán betegségek kezelésére, hanem megelőzésképpen és hozamfokozóként is. A túlzott felhasználás vezetett az antibiotikum rezisztens baktérium törzsek számának emelkedéséhez. Ennek a veszélye ma már komoly gond világszerte. Az Európai Unióban az antibiotikumok hozamfokozóként való használatát 2003-ban tiltották be, azonban a szakhatóságok által vezetett statisztika szerint a tagállamok felhasználása között jelentős különbségek vannak. Az állattenyésztés során felhasznált szerek nagy aránya jut a szerves trágyán keresztül a mezőgazdasági területekre, ahol a talajból a növények felveszik, és szöveteikbe akkumulálják azokat. Míg arra nincs bizonyíték, hogy az emberi szervezetre milyen hatással van ez a felhalmozódás, a növények fejlődésére bizonyított a hatásuk. Ennek a tanulmánynak a célja az, hogy bemutassa az antibiotikumok és maradékanyagaik hatását a kertészeti növényekre. A nyersen való fogyasztás következtében a zöldségek jelenthetik a legnagyobb kockázatot a gyógyszerhatóanyagok felhalmozódása és a rezisztens baktériumok humán kitettsége terén. A téma kutatási eredményei rámutatnak, hogy foglalkozni kell az antibiotikum-tartalmú gyógyszerek felhasználásának csökkentésével. Kulcsfontosságú kérdés lehet az állattartó gazdaságok megfelelő tájékoztatása a túlzott felhasználás árnyoldalairól.

Kulcsszavak: antibiotikumok, antibiotikum rezisztencia, kertészeti növények, szerves trágya, zöldségnövények

Introduction

Antibiotics are among the most important discoveries in the 20th century (Davies, 2010). Over production and increasing use of antibiotics can be seen in human medicine and also in agricultural production for more than 60 years. This application could significantly improve public health and the productivity of agriculture worldwide (Knapp, 2010). They truly have great importance, but a real danger is the development of antibiotic resistance form of different organisms due to the intensive application and overuse. The value of antibiotics should not be underestimated; humans and animals are totally dependent on them in the treatment of infectious diseases, however, they should never be considered as the only tool in therapy (Davies, 2010). Lately, these substances used for human and animal therapies, were in focus because of their potential environment polluting effects (Jjemba, 2002). New chemicals are conducted in the 20th century without knowing anything about their effects on the environment and the human organism.

The European Community made it necessary from 1980 of making serious research activities regarding this key-important topic of antibiotics danger. In the past it was not usual to do risk assessments for the safe application of various medicines. Today it has become an everyday practice to do that before they introduced new veterinary products. This protocol on the other hand is still under development for the human medicines (Szatmári, 2012). According to literary data, more than the half of human antibiotics' consumption is in relation with the food-production (Moller, 1999). Fifty to ninety per cent of them is excreted in the urine and feces of humans or animals and its original form might be broken down into different metabolites (Bougnom, 2017). Serious amount of these chemical compounds and metabolites are released into the environment: flushed in the toilet, thrown out as wastes, or mixed into feed of livestock and used as performance-enhancing in sub therapeutic dose during their production (Jjemba, 2002; Graham, 2007).

The occurrence of antibiotics in manure and in the soil of fertilized fields

The absorption of antibiotics is not complete in the digestive system of animals, or after their absorption, they do not always break down completely during the metabolism of animals. Because of this, significant amount of antibiotics is excreted in the urine or excreted in the feces. After these processes antibiotics and their metabolites gets very often into the farmyard manure products. The manure is used worldwide as the source of nutrients and organic matter for plants, and to enhance soil quality, especially in organic and sustainable farming systems (Kumar, 2005). Because these medicines are very often chemically stable compounds, therefore they can be relatively recalcitrant for long time in the environment, and also in plants, grown in polluted soils or in polluted water sources. There is a high risk that the antibiotics can be accumulated in these plants exposing unknown risks on consumers (Chen, 2017). Szatmári et al. (2012) studied the elimination of a relative new derivate of tetracycline called doxycycline from the body of swine. Their results showed that after they use of doxycycline in therapeutic dose significant quantity of this antibiotic appeared in swine manure. Its concentration decreased with the fermentation of manure but still remained in high concentration at the time at applying the manure in the field for fertilization, so polluting the soil. In the soil the concentration decreases with time, but this decrease is known to be highly dependent on the soil depth and the type of the soil, the management and also several other environmental factors. Twenty weeks after spreading the manure on the field, the researcher indicated about 30-60 µg/kg antibiotic concentrations (Table 1) in each soil layers tested. It was also shown that the antibiotic in these concentrations temporary inhibited the life processes of microorganisms living in the soil. Nitrogen transformation and energy-producing processes of soil bacteria were shown to be inhibited, as well (Szatmári, 2012).

According to Jjemba et al. (2002) the effects on soil processes can be different depending on the type of soil and other factors like chemical structure of the agent of antibiotics. Among the agents some can be found to be degraded very quickly (tylosin), however, some is degrading slowly (ivermectin), and some is degrading very slowly *(*the tetracyclines). The speed of degradation of the agents depends not only on the chemical structure but also on the type of the fertilized fields. For example, the ivermectin degrades faster on clay soils, against the metronidazole, degrades on sandy soil much faster. Mutual effects of various chemical compounds of antibiotics could be considered also important. The effect can be additive, antagonistic and synergistic, so additive they can increase or decrease their effect on the environment (Szatmári, 2012).

Table 1. The change in concentration of doxycycline in manure samples, during the farm fermentation (Szatmári, 2012)

Weeks	Doxycycline, average±SD (n=3) (mg/kg)
0	87.5±1.25
1	67.47±1.15
2	43.98±14.25
3	45.81±6.48
4	33.81±0.47
6	22.52±0.21
8	14.69±5.97
10	11.28±4.93
12	9.37±1.58

After the use as human treatment, antibiotics get into sewers, and unfortunately from sewers many chemical compounds are not properly removed, because the methods generally used for wastewater treatment are not able to break down of antibiotics or their metabolites. Thirty-seven per cent of sewage sludge is used as biosolids on agricultural lands in the European Union (Jjemba, 2002). Due to the reasons indicated above, a large amount of biological waste or manure containing antibiotic residues can ended up on agricultural fields. During a research in China, highest concentrations of antibiotics were found on the fields belonging to animal husbandry farms. The content of chlortetracycline, sulfamide and quinolines exceeded the ecotoxic level given by the World Organization of Animal Health (100 µg/kg; Li, 2011). Like any other xenobiotic chemical compound, the adsorption to the soil colloids of compounds used in human and animal medicine for therapy depends on the organic materials, pH, concentration of mineral materials, clay content and temperature of the soil. The adsorption of organic materials in the soil can decrease the effect of therapeutic antibiotics on plants, because their absorption can only happen solubilized in water. It is not only dependent on the quantity of organic materials but on their quality, as well. The residues of antibiotics pollute the groundwater especially if they adsorption on soil colloids is poor (Jjemba, 2002).

The dangers of pollution with antibiotics in cultivated plants

The antibiotics spreaded out on the fields with the used manure can be also dangerous, because the plants grow for human food or animal fodder might adsorb them from the soil. Kumar (2005) conducted an experiment to study how corn (*Zea mays* L.), spring onions (*Allium cepa* L.) and cabbage (*Brassica oleracea* L. Capitata) adsorb different kind of antibiotics from the soil. Chlorine-tetracycline got into all three plants, unlike the tylosin. The concentration of chlortetracycline was low in plant tissues (2-17 ng/g wet weight) but the concentration rose with increasing concentrations of antibiotics in soil. They also made an experiment with cabbage, cultivated in pots (*Brassica oleracea* L. Capitata) and spring onion (*Allium cepa* L.) of using sandy soil. The results were similar to those mentioned before; plants absorbed the chlortetracycline but not the tylosin (Table 2).

Table 2. Concentration of antibiotics in plant tissues after 3 and 6 weeks of treatment (Kumar, 2005)

Antibiotic (ng/g fresh weight)	Green onions		Cabbage	
	3 weeks	6 weeks	3 weeks	6 weeks
Tylosin	LCD*	LCD*	LCD*	LCD*
Chlortetracycline	14.4±2.3	12.8±1.7	11.4±2.1	10±1.8

*LCD means the concentrations lower than could be detected.

While there is no evidence, that the bioaccumulation of individual therapeutic antibiotics means a notable danger on plant consumers, it is not a question that these compounds might have harmful effects on the growth of higher plants and crops. This was the effect of therapeutic antibiotics on field crops is very different depending on the type of the antibiotics, plant species, and soil types (Jjemba, 2002). Batchelder (1982) found the same result during his experiments, according to those the oxytetracycline and chlortetracycline had negative effect on the yield in bean (*Phaseolus vulgaris* L.) production. The decrease in yield was accompanied with the reduced concentration of Ca, K and Mg. However, these two antibiotics increased the growth of radish (*Raphanus sativus*) and wheat (*Triticum aestivum*) (Jjemba, 2002). According to the finding of Hu et al. (2010) the distribution of antibiotics is not homogeneous in plants. Most of the antibiotics absorbed by plants can be found in leaves, lower concentrations in the stem and the lowest in the root. However, the results of other experiments are contradictory to these statements. Chen et al. (2017) published the results of a research about the absorption of tetracycline and sulfamethoxazole in Chinese cabbage (*Brassica rapa chinensis*) and water spinach (*Ipomoea aquatica*) harvested from soil. Both plants absorbed the sulfamethoxazole more effectively in comparison with the tetracycline. But in this experiment the leaves and the stem worked like a channel, and not as a storing part for accumulation of antibiotics. Most of antibiotic residues stored in the root. The accumulation of tetracyclines were higher than sulfamethoxazole in both plants.

The threat of antibiotic resistant bacteria species

In the last few decades an increasing number of antibiotic resistant bacterium species were noticed, which caused more and more serious and hardly manageable and sometimes even fatal infections. Before the discovery of antibiotics there were no resistant plasmids (Huges, 1938). The first penicillin resistant bacteria were noticed shortly after the start of penicillin application for medication processes (North, 1946; Barber, 1947). Since that, after introducing each new antibiotics, several new resistant bacteria were found (Levy, 1997). Nowadays if there is enough concentration of antibiotics in the surroundings of some bacterium species, viruses and phages, they are able to become resistant against the active agent (Aarestrup, 1999). Many factors are known that can help to develop and spread antibiotic resistance: waste-water disposals, waste-water and sewage sludge, pharmaceutical companies, aquacultures, liquid manure storages and agricultural farmlands treated with manure (Berkner, 2014). The soil examinations of Knapp et al. (2010) also showed that the antibiotic resistant genes have increased significantly in every groups of antibiotics studied since 1940, especially in tetracyclines, where the occurrence of resistant genes was 15 times higher compared to years in 1970's. The spread of the resistant genes in high concentration of antibiotics can influence the structure and activity of environmental microbial populations, and these changes can have an impact on human health in the future (Martinez, 2009). It was proven that antibiotic resistant plasmids can spread out to farm fields with swine manure (Smalla et al., 2000). Yang et al. (2013) conducted a research with celery (*Apium graveolens*) and cucumber (*Cucumis sativus* L.) studying if antibiotic resistant bacteria could be penetrated into plants cultivated on the soil fertilized with manure of animals that had been treated with antibiotics. Their results showed that the occurrence of resistant bacteria in the manure depended on the animal species and the relative quantity of antibiotics that were used in the animals. They also found the resistant bacteria in plant tissues; the highest concentration was showed in the root. In the study of Marti (2013) multiple antibiotic resistant bacteria were showed in tomato (*Solanum lycopersicum*), cucumber (*Cucumis sativus*), pepper (*Peper nigrum*), carrot (*Daucus carota*), radish (*Raphanus sativus*) and salad (*Lactuca sativa*). According to their results, in manure fertilized soil an increase of antibiotic resistant bacteria was found, but in vegetables grown on these fields this was not detected. This finding could be more important in the case of vegetables consumed by humans as a row material without heat treatment, so bacteria living in the soil can be directly threaten for consumers. Zhang et al. (2017) in the study with cabbage (*Brassica chinensis* L.) detected that the antibiotics were adsorbed by the plant from the hydroponic environment. The absorption was selective against several antibiotics and the absorbed amount depended on the concentration of antibiotics. The accumulated antibiotics had an impact on the growth of the plant, and increased the number of resistant bacteria and genes in the plants, which can be important if considering the possible transfer of these genes through the food chain.

Predicted environmental concentrations (PEC) of residues from veterinary sources

Spaepen et al. (1997) developed estimation for predicting the residual concentrations from veterinary sources in soil (PEC) based on the nitrogen and phosphorus requirements of plants. Although this estimation concerns to cattle, poultry and swine, it can be easily modified for manure of other animal species.

The estimates are based on assumption about:

1. The active agent given to animals is excreted via the urine or feces (the formation of metabolites is not taken into consideration by the estimation);
2. The treated animals are kept in stables;
3. The manure produced by all animals is stored only on the same place;
4. The manure is stored on the same place at least for a year.

Essential model developed by the authors mentioned before is based on the Q=D x BW x T x N equation, where:

Q: all amounts of the agents the animals was treated with (mg/year/place);

D: individual dose of medicines (mg/kg unit of weight);

BW: the body weight of animals (kg);

T: individual numbers of treatment by animal;

N: the number of animals housed in the stable.

The typical PEC, i.e. the estimated environmental concentrations of veterinary residues from different animal species, is based on this equation. According to Jjemba (2002), although the assumptions in this model are reasonable, various practice ways of collection and storage of manure is not taken into consideration by this model. The PEC numbers do not reflect the degrading fractures of therapeutic compounds in different soils. This information is usually missing, so these numbers can be used for estimations only with reservation. The proportions of different active agents, compared to each-other, are also an important key-factor.

Table 3 shows the quantity of manure related to animal unit and the maximum concentrations of residues that can be predicted, so the PEC number.

According to the data indicated in Table 2, if considering a broiler chicken that produce 37.3 kg manure a year, and calculating with the highest does of antibiotic (100 mg/body mass kg), then the environmental concentration of therapeutic compounds (PEC) is predicted to 252.57 ɥg/kg live weight. If body weight is taken also into consideration, a chicken can produce 328.41 ɥg/bird residues. So, a broiler chicken farm with 2,000 chickens excrete 24.49 g residues in 74,600 kg (74.6 t) manure to the fields (1 t = 0.33 g residues).

Table 3. The maximal concentrate of residues that can be estimated in manure in case of different antibiotic dosage (Jjmeba, 2002)

Animal species	Body weight (kg)	Excretion (kg/place/year)	PEC (ɥg/kg) with different doses of antibiotics		
			1 mg/kg body weight	25 mg/kg body weight	100 mg/kg body weight
Calf for slaughter	160	4,660	2.67	66.54	266.18
Dairy cow	500	20,391	0.29	7.33	29.33
Beef cattle	500	9,186	0.43	10.76	43.06
Bull	1,200	20,075	0.7	17.5	69.9
Piglet	20	754	1.62	40.6	163.39
Fattening hog	95	1,764	1.12	28.07	112.27
Grown-up hog	130	2,829	0.34	8.61	34.42
Sow and litter	100	4,928	0.18	4.54	18.16
Broiler chicken	1.3	37.3	2.52	63.14	252.57

In case of deep litter, 1,000 broiler chickens produce 23 kg/t N with the manure. The maximum amount, that can be spread on fields without toxic level of nitrate is 170 kg/ha N (Berényi, 2005). According to this, 7.3 t deep litter manure can be spread out onto 1 hectare. So, the manure amount of the broiler farm with 2,000 chickens can be spread out on minimum 10 hectares. Considering this procedure 2.397 g antibiotic residue will be delivered onto 1 hectare of field. Divide this amount to 1 m^2 area, 239.7 µg antibiotic will pollute the land. The danger of this depends on the characteristics of the soil, animal species, type of agent and the plants, absorbing and accumulating the antibiotics in their tissues.

The European Medicine Agency (EMA) continuously publish statistical data and frequently reporting the medicine consumption of the inhabitants of member states. You can see the medicine consumption of each country, the animal and human use is shown separately. Table 4 shows the medicine consumption in different European countries in the year 2014. It can be seen that 40% of the countries is far over the highest PEC number in medicine use for animal treatments, and the average value of all countries is also far over that. The total consumption for both animal and human purposes shows significant differences among countries. This fact demonstating us, that in both sectors, there is a potential opportunity to decrease the medicine consumption in several countries by enhancing for instance the efficiency of medicines (European Food Safety Authority, EFSA, 2017).

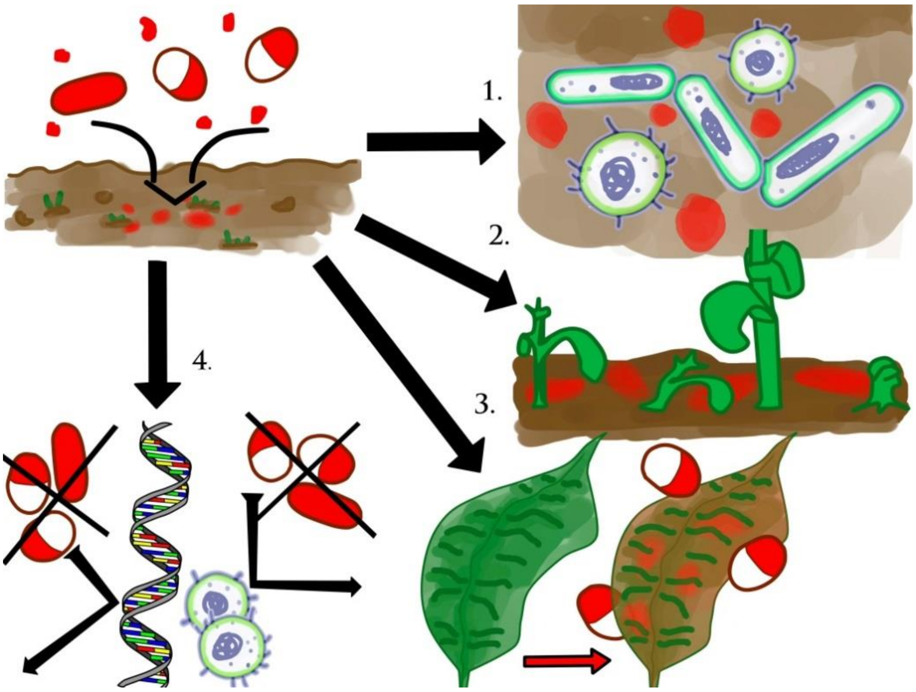
Table 4. The consumption of medicines of European countries in 2014 (EFSA, 2017)

Consumption in mg/kg biomass					
Country	Humans	Animals	Country	Humans	Animals
Austria	70.9	56.3	Italy	166.9	359.9
Belgium	153.4	158.3	Latvia	81.6	36.7
Bulgaria	116	82.9	Lithuania	102.5	35.5
Croatia	128.4	114.8	Luxembourg	130.2	40.9
Cyprus	124.7	391.5	Nethetlands	49.9	68.4
Czech Republic	99.4	79.5	Norway	140.1	3.1
Denmark	143.5	44.2	Poland	110.7	140.8
Estonia	71.7	77.1	Portugal	116.1	201.6
Finland	139.2	22.3	Romania	181.7	39.1
France	174.2	107	Slovakia	140.2	65.9
Germany	56.9	149.3	Slovenia	105.5	33.4
Hungary	86.6	193.1	Spain	112.6	418.8
Iceland	101.7	5.2	Sweden	119.8	11.5
Ireland	155.6	48	United Kingdom	128.7	62.1
All				123.7	151.5

Global situation, legislation

As already have mentioned before, the studies and research about this topic are diversified and many times they are conflicting. According to the results of researches up to this point, the antibiotics and their residues provide risk in four different ways when they get into the soil (Figure 1):

1. through influencing the organisms living in the soil
2. through influencing the growth of plants
3. through accumulating in the plant tissues
4. through helping the evolving antibiotic resistant genes and bacteria

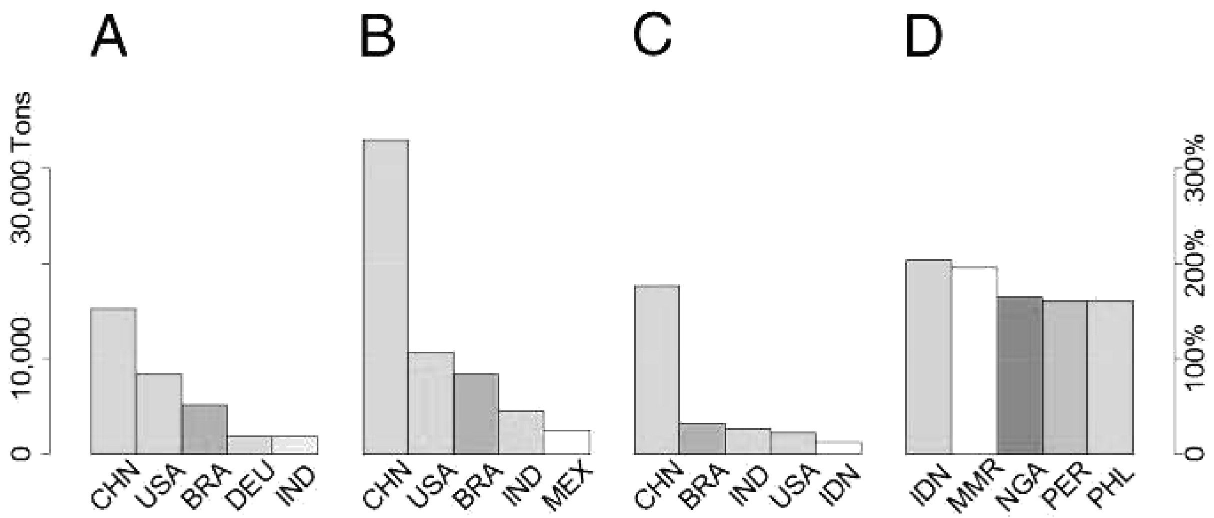


Red color marks antibiotic contamination. Presence of antibiotics: 1. affect soil fauna, 2. affect plant growth, 3. get accumulated in plants, 4. result of the antibiotic resistance (original figures from the author).

Figure 1. The four ways how antibiotics and their residues can be a threat when getting to soil

In the European Union, the supplementation of antibiotics to the diet for growth promoters is reduced from 2000 (Graham, 2007). In the regulation 1831/2003/EC the use of antibiotics for growth promotion is prohibited from the 1st of January 2006 (Terényi, 2016). Compared to many countries in the world, Hungary is a leader country of indicating of antibiotic reduction, which can reduce the number of antagonistic beneficial bacteria in the arable soil-plant systems (Biró et al., 1999). If those bacteria are diminished, then artificial microbial inoculums can be used to improve the compost- and/or the soil quality (Ködöböcz et al., 2005) this. The same recommendation of reducing and/or prohibiting of antibiotics was made in the U.S.

but this rule was not introduced yet (Berkner, 2014). The National Action Plan of the U.S., handling the battle against antibiotic resistant bacteria, highlights that fight should be made against the spread of antibiotic resistance on each level. The World Health Organization (WHO) countries from South East Asia also take the commitment to deal with antibiotic resistance in the statement of Jaipur. This progress is also happening in Afrika, which was started by the work of GARP (Global Antibiotic Resistance Partnership), and this action was going through wide coalition of government leaders and the private sector. The Center of Diseases Dynamics, Economics & Policy (CDDEP) is still collecting reliable data from all around the world about use of antibiotics and the resistant bacterium species, and all this information can be reached online on the site of Resistance Map (Gelband, 2015). So, the regulation is the most up-to-date in the EU, still unfortunately there is no limit even for reduces of medicines and hormones in drinkable water in the EU either, because there is not enough scientific evidence to develop consensus about the limits for public health (National Center for Public Health, 2016). According to the forecasts of Van Boeckel et al. (2015) the consumption of antibiotics can increase with 99% in the developing countries until 2030 (Figure 2). The global consumption of antibiotic compounds in animal husbandry was 63.151 (±1.56) tons in 2010, and this will increase with 67% to 105.596 (±3.605) tons until 2030. The two third (67%) of this growth will come from the increasing numbers of farm animals. The other one third (34%) can happen because of the changing of farming practices. The major part of animals will be raised on intensive farms until 2030.



(A) The five largest consumers of antimicrobials in livestocks in 2010. (B) The five largest consumers of antimicrobials in livestocks in 2030 (predicted). (C) Largest increase in antimicrobial consumption between 2010 and 2030. (D) Largest relative increase in antimicrobial consumption between 2010 and 2030: CHN, China; USA, United States; BRA, Brazil; DEU, Germany; IND, India; MEX, Mexico; IDN, Indonesia; MMR, Myanmar; NGA, Nigeria; PER, Peru; PHL, Philippines (Van Boeckel, 2015).

Figure 2. Information about the antibiotic consumption

The safest way to avoid the exposition of plants with antibiotics is to provide the adequate degradation of chemical compounds in manure, before spreading out to the fields (Jjmeba, 2002). The amount of residues can be reduced substantially with composting. In agricultural practice it is variable that how long is the slurry stored. Usually long time stored and fresh slurry are also used. From the fresh slurry, the residues of antibiotic treatments can get to the field in constant concentration (Szatmári, 2012). Optimizing the process of anaerobic degradation of the slurry, which have been used for producing methane and biogas also can be an effective way to remove antibiotic residues (Berkner, 2014). This danger is the same with manure, which can be treated before any agricultural use of reducing antibiotic risks and also to improve the survival of several beneficial microorganisms, if treated beforehand (Bayoumi et al. 1995). According to an information from the United Kingdom, the storage time is suggested, to be between 0 and 48 months (Boxall et al., 2003; Kümmerer, 2004; Sarmah et al., 2006; Szatmári, 2012). Another method, that can be used to remove antibiotic residues from the soil, is the remediation. For example: fitodeporcination, when at first low economic value of plants are applied for a short time on the polluted field; so these plants adsorb the antibiotic residues, and then higher economic value of plants are cultivated. However, to make this method working well, the suitable plants need to be tested (Jjemba, 2012).

Suggestions

The safest way to avoid the exposition of plants with antibiotics is to provide the adequate degradation of chemical compounds in manure, before spreading out on the fields. The amount of residues can be reduced substantially with fermentation and composting the manure or slurry. From the fresh slurry, the residues of antibiotic treatments can get to the field in constant concentration. Optimizing the process of anaerobic degradation of the slurry, used for producing methane and biogas also can be an effective way to remove antibiotic residues. This danger is the same with manure. A good method for the removal of antibiotic residues from the soil, is remediation, including fitodeporcination. Wider knowledge is required about what happens to antibiotics when they get to the environment and also about antibiotic resistance. Only after it is important to develop proper strategies to treat accurately the problem. The legal regulation is needed to be kept up-to-date, as weel, because there is a big potential in improving the use of medicines and pharmaceutical products. The application of antibiotics as growth promoter and for prevention already has been forbidden in the EU. This contributes to the reduction of antibiotic consumption, but it would be also important to check the compliance for these laws. Efforts are needed to enhance the storage of manure before it reaches the fields, so the exposition of plants to antibiotics could be reduced to minimal level. Because of the raw consumption of vegetables, there is a higher risk of transferring multitolerant bacteria and fungi through the food chain, for this reason more research is required to estimate the effects of contaminated foods.

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