Awareness of antibiotic resistance for the environmental health and sustainable development: a cross-sectional study

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Abstract. Antimicrobial resistance (AMR) is a significant concern for global health and has been recognized as a threat to the world’s sustainable development affecting several sustainable development goals (SDG). Uncontrolled and unjustified use of antimicrobial drugs in both agriculture and medicine, leads to the emergence of new strains of microorganisms resistant to antibiotics that can be distributed through the environment and poses both direct and indirect threat to public and environmental health. The systematic literature reviews and cross-sectional study to assess the awareness and attitude to antimicrobial resistance among veterinary and medical students of Ukrainian universities demonstrates the relationship between the antibiotic resistance issue and its influence on environmental health as the important determinant of global health and the Sustainable Development Goals. Both medical and veterinary students acknowledged the antimicrobial resistance to a certain extent. However, differences among the responses of target groups demonstrate that medical students are better trained on antimicrobial prescriptions to humans and more familiar with the protocols of treatment of different diseases of humans. Findings can be used for the development of educational activities aiming to improve knowledge on antimicrobial use, particularly in the framework of One Health approach.

1. Introduction
Antimicrobial resistance (AMR) is a significant concern for global health and has been recognized as a threat to the world’s sustainable development, impacting the achievements of several of the 17 sustainable development goals (SDG). Still there is no single indicator for SDGs specific to AMR as the challenge of AMR directly involves environmental and compromises social and economic sustainability aspects. Uncontrolled and unjustified use of antimicrobial drugs in both agriculture and medicine, leads to the emergence of new strains of microorganisms resistant to antibiotics [1–3]. The environmental implications of the antimicrobials lifecycle (both human and veterinary) can contribute to the acceleration and spread of resistant organisms [4–7]. Linking antimicrobial consumption in animals, presence of antimicrobials in the environment, the spread of antimicrobial resistant microorganisms to development of AMR infections in humans is complex due to the ecological essence of the selection pressure for resistant pathogens and of indirect routes of transmission through the environment [2, 5, 8–11].
The Global action plan on antimicrobial resistance considers the level of awareness and understanding of AMR among key stakeholder groups, that include the human health, animal health, food sector, environment and plant health sectors, to be one of five strategic objectives [12–14]. Appropriate education and training of future veterinarians and physicians is critical for good antimicrobial stewardship and should be supported by development of curricula that fosters best practice in antimicrobial use [15, 16]. The COVID–19 disruption has significantly impacted the provision of both medical and veterinary education, highly affecting courses teaching clinical and professional skills [17–19]. Under such conditions a e-learning with the delivery of educational resources through the Internet and provision of a supportive online environment in University is critical for sustainability of education activities [20–23].

2. Research objectives
Geoecological research methodology allows at a higher scientific level to approach the assessment of the impact of technogenic processes, namely the placement of wind turbine generators (WTG) and the formation of the wind power plant (WPP) site, on the state of the components of the environment - avifauna and chiropterofauna, which are considered as one of the important bioindicators of the ecosystem state.

The objectives of the research were to assess the role of antimicrobial resistance issues in sustainable development and environmental health, as well as to carry out preliminary evaluation of awareness on antibiotic resistance among veterinary and medical students in Ukraine, as representatives of target stakeholder groups, for their current potential to assure environmental health and the sustainable development goals (SDGs) realization.

For achievement of the objectives the following research questions were addressed:

- Research Question 1 (RQ1): What is the relationship between AMR knowledge and environmental health and SDG?
- Research Question 2 (RQ2): What is the level of AMR awareness among veterinary and medical students?
- Research Question 3 (RQ3): What is the difference between knowledge regarding AMR of veterinary and medical students?

3. Methodology of research
Addressing RQ1, we applied the method of systematic literature reviews (SLRs); For RQ2 and RQ3 a sample survey method was used.

3.1. Study retrieval and datasets
The compliance of current study with the Sustainable Development Goals (SDG) (https://sdgs.un.org/goals) were assessed in the Dimensions.ai database from Digital Science (https://www.dimensions.ai). We chose Dimensions.ai because the free version of the platform provides an open search of more than 124 million publication records and associated metrics for individual users [24].

Search terms have been developed to gather data on the key topic areas (I–V) related to the objectives of our study and ten–year period by application Publication year filter were chosen in the range from 2012 to 2021. Sets of keyword searches were narrowed from determining the impact of antimicrobial resistance awareness on sustainable development (set No I) and environmental health as one of the key determinants of global health, along with human and animal heath, when it comes to AMR (set No II) through students’ knowledge as the main human resource on antimicrobial resistance awareness (set No III) to the significance of training on AMR key target groups, such as veterinary (set No IV) and medical students (set No V):
• Set No I. (antimicrobial resistance) AND (awareness OR knowledge)) AND (sustainable
development);
• Set No II. (antimicrobial resistance) AND (awareness OR knowledge)) AND (environmental
health);
• Set No III. (antimicrobial resistance) AND (awareness OR knowledge)) AND (students);
• Set No IV. (antimicrobial resistance) AND (awareness OR knowledge)) AND (veterinary
students);
• Set No V. (antimicrobial resistance) AND (awareness OR knowledge)) AND (medical
students).

3.2. Instruments and participants
A cross-sectional study was carried out by using a random sample online survey among veterinary
and medical students in Ukraine. Non-random criteria were used for selection of individuals,
as this research aimed to develop an initial understanding with respect to antibiotic awareness
among university students with different backgrounds. Thus, the target population of the study
was selected based on the direction of higher education being obtained. The current study did
not seek to test any hypothesis about a larger population; thus it was carried out using voluntary
responses.

For this purpose, 113 (35.4%) medical and 206 (64.6%) veterinary students (table 1)
representing different regions of Ukraine, namely Kyiv, Poltava, Sumy, Vinnytsia, and
Zaporyzhia, were involved in the study, bringing the total number of respondents to 319.
The target population included both male (22.57%) and female (77.43%) students from year
one (preclinical) to year six (clinical). The majority of respondents reported having taken
antibiotics more than a year ago (34.5%) and one fifth have taken them within the past month
(19.7%). There was no significant difference in the last intake of antibiotics among veterinary
and medical students, however more veterinary students claimed they have never taken antibiotics
(3.4% compared to 1.77%). Individuals between 16–18 (55.17%) and 19–24 (40.13%) years old
formed the most populous age groups (95.3%). Even though year-one students do not take any
core clinical courses, they were enrolled in the study in order to evaluate their awareness on
AMR issues based on their theoretical background.

A link to a 25 questions survey was distributed in social messengers to different student
groups and conducted online via Google Forms. The instrument was modified from WHO
multi-country public awareness survey in the framework of a program to raise awareness of
antibiotic resistance among the population [25]. The survey was available online for a period from
December 2021 to January 2022. Students were asked questions on their demographic, personal
antibiotic use (table 1), attitude, awareness and contributory factors to antimicrobial resistance
(https://forms.gle/L5bxTiCJXzrfjPPW9). For self-reported awareness, behavior, knowledge,
and attitude towards the antibiotic usage the questionnaire included multiple choice questions,
statements testing knowledge using a true or false answer, and statements assessing attitudes
and behaviors by seeking agreement using a 5–point Likert scale – strongly agree, agree, neither
agree nor disagree, disagree, strongly disagree. In addition, there was an option of ‘I do not
know /can not remember’.

3.3. Data processing and analysis
The collected data were initially summarized in Microsoft Excel and checked for completeness
and consistency. Repeated questionnaires were excluded from analysis. Numerical data were
checked for possible data gaps and need for categorization was considered. Descriptive statistics
were obtained for all variables of interest from the survey by education background for medical
and veterinary students.
Table 1. Characteristics of the respondents (n = 319).

| Feature Category of Feature | Number (Percent) Veterinary | Number (Percent) Medical | Total (Percent) |
|-----------------------------|-----------------------------|-------------------------|-----------------|
| Gender                      |                             |                         |                 |
| Female                      | 166 (80.%)                  | 81 (71.7%)              | 247 (77.4%)     |
| Male                        | 40 (19.4%)                  | 32 (28.3%)              | 72 (22.6%)      |
| Age (years)                 |                             |                         |                 |
| 16–18                       | 133 (64.6%)                 | 43 (38.1%)              | 176 (55.2%)     |
| 19–24                       | 67 (32.5%)                  | 61 (54%)                | 128 (40.1%)     |
| ≥25                         | 6 (2.9%)                    | 9 (8%)                  | 15 (4.7%)       |
| Antibiotics use             |                             |                         |                 |
| Never                       | 7 (3.4%)                    | 2 (1.8%)                | 9 (2.8%)        |
| More than a year ago        | 64 (31.1%)                  | 46 (40.7%)              | 110 (34.5%)     |
| In the last year            | 16 (7.8%)                   | 8 (7.1%)                | 24 (7.5%)       |
| In the last 6 months        | 29 (14.1%)                  | 24 (21.2%)              | 53 (16.6%)      |
| In the last months          | 45 (21.8%)                  | 18 (15.9%)              | 63 (19.7%)      |
| Can not remember            | 45 (21.8%)                  | 15 (13.3%)              | 60 (18.9%)      |

The post hoc power was estimated by using G*Power version 3.1.9.4. The minimum sample size required to show a difference between groups was 193 at an alpha probability value of 0.05 and beta of 0.80.

Chi–square and Fisher’s Exact Test were used to determine associations at an alpha level of ≤ 0.05. This initial step was for variable selection for further models, possibly logistic regression. The data analysis for this paper was generated using SAS software [26].

4. Results of research

4.1. The results of a systematic literature reviews

The number of records retrieved from each search strategy is summarized in table 2 by research contributions (number of publications), open access supported initiatives (percentage of total publications), research (grants) and publication of their results (clinical trials and policy documents). In terms of qualitative parameters (screening revision by title/abstract) we can assume that medical and veterinary students are of primary concern of the AMR awareness, as the III search of scientific publications shows the above categories targeted. The results of search set V demonstrates that veterinary students are also included in the category of medical students, so the sample of scientific publications on the knowledge of veterinary students (set IV) is the smallest. Another reason may be the study gap in this area but that was beyond the objectives of our research.

The search results in Dimensions.ai revealed the overall growth of publishing activity since 2017, which can be explained by implementation of the EU One Health plan on antimicrobial resistance [27] and growing research interest for environmental pathways and barriers study [28, 29]. The highest number (134) of grant-supported activities for the search set II indicates contribution of environmental health toward One Health concept [8–10, 30]. In the field of
Table 2. Quantitative search results for I – IV sets in Dimensions.ai.

| Set | Publications | Open access | Clinical trials | Grants | Patents | Policy documents |
|-----|--------------|-------------|-----------------|--------|---------|-----------------|
| I.  | 62777        | 19459 (31%) | 1               | 53     | 1479    | 5376            |
| II. | 156504       | 58183 (37.2%) | 9             | 134    | 16545   | 5167            |
| III.| 76430        | 27572 (36.1%) | 19            | 82     | 5504    | 2521            |
| IV. | 21489        | 5603 (26.1%) | 1              | 8      | 1718    | 1059            |
| V.  | 63808        | 21128 (33.1%) | 11            | 19     | 4322    | 2350            |

research, most publications (results for all 5 searches) cover Biological Sciences, Medical and Health Sciences and Public Health and Health Services. General questions (set I and II) cover the field of Engineering, and Chemical Sciences, as well as, together with the results of search set IV – Agricultural and Veterinary Sciences, others (specialized) – Clinical Sciences, and medical students (set V) – Medical Microbiology.

Considering the fact that antimicrobial resistance challenges sustainability and confronts both environmental and public health and the 2030 Agenda [31], we studied the compliance of the search I–V results with the Sustainable Development Goals. According to the results of the publications metadata description, the considered subject most corresponds to the following SDG:

- **SDG 3. Good Health and Well Being** (4.0% of the total number of publications – the results of the implementation of set I, 4.4% – set II, 5.0% – set III, 3.7% – set IV, 5.2% – set V), as with effective antibiotics use maternal, neonatal and child deaths can be prevented, and epidemics of communicable diseases and environmental contamination by waste can be managed;
- **SDG 2. Zero Hunger** (4.4% of the total number of publications – the results for the search set I, 2% – set II, 0.9% – set III, 1.2% – set IV, 0.7% – set V) as the antimicrobial use ensures sustainable food production systems;
- **SDG 4. Quality Education** (0.3% of the total number of publications – the results for the search I, 0.2% – set II, 0.5% – set III, 0.4% – set IV, 0.5% – set V) – testify the need for relevant training of the target population.
- **SDG 12. Responsible Consumption and Production** (1.7% of the total number of publications – the results for the search set I, 0.7% – set II, 0.3% – set III, 0.4% – set IV, 0.3% – set V) indicates the importance of responsible use of antimicrobials and significant contribution of environmental health and veterinary medicine for the benefits of humans and skills to meet societal needs.
- **SDG 13. Climate Action** (1.5% of the total number of publications – the results for the search set I, 0.7% – set II, 0.4% – set III, 0.5% – set IV, 0.3% – set V) – shows potential alterations in the diversity and complexity of environmental microbial populations around the world that may result in selection of resistant isolates.

Therefore, based on the current analysis, we can assume that antibiotic resistance awareness has a significant influence on global health and wellbeing as SDG 3, SDG 12 and SDG 13 correlate with the areas of environmental health, agriculture and food underlined by SDG 2,
and supports the need of extra attention to the training of target stakeholder groups (SDG 4 – Quality Education).

4.2. Levels of knowledge around the appropriate use of antibiotics: the results of a survey

Among 319 participants from Ukrainian universities, who completed the survey, the majority of the students of both groups (72.41%) answered that they had consulted their physician regarding antibiotics administration, such as time and duration of administration. Among veterinary students 71.84% claimed that they consulted their physician for the instructions on antibiotics administration, 15.53% referred to the drug’s instruction, and 12.63% did not remember or did not contact a doctor. Among medical students 73.45% answered “yes” to the question “Has the doctor (pharmacist) determined the procedure for taking antibiotics?”, 15.04% referred to the drug’s instructions, and 11.5% did not remember or did not contact a doctor.

Surprisingly high number of respondents of both groups claimed that they bought the antibiotics in the pharmacy – 90.91%, on the opposite only 1 veterinary student bought them via Internet – 0.31%, and 3.45% of respondents stated that they had some left over from the previous prescription or got them from a family member or a friend, 5.33% could not remember where they got the drugs.

Among veterinary students 85.44% agreed that one should stop taking antibiotics once all the pills are taken as prescribed after starting treatment, compared to 95.58% of medical students. Only 4.42% of medical students believed that one should stop taking antibiotics when they get better, as opposed to 12.14% of veterinary students who claimed the same and 2.43%, who did not know when to stop taking antibiotics.

Both categories of respondents disagreed with the statement that “You can use antibiotics that have been prescribed to a friend or family member if they have been used to treat the same disease” – 87.15%, 8.78% agreed with the statement, and 4.08% did not know. There was no significant difference in answers among veterinary and medical students to this question.

On the other hand, almost twice as many veterinary students didn’t know if “You can buy the same antibiotics or ask your doctor for them if they have helped you before with similar symptoms”, 10.19% compared to 5.31% of medical students. Nonetheless, 69.59% of both categories disagreed with that statement.

There was some misunderstanding around which conditions can be treated with antibiotics (figure 1).

![Figure 1. Percentages of options selected by respondents regarding disease conditions treated with antibiotics (* – P < 0.0002, ** – P < 0.0001).](image-url)
The majority of respondents (81.5%) associated antibiotics with urinary tract infection treatment and 71.5% surveyed correctly identified conditions such as skin/wound infections as treatable with antibiotics. Around 17% of all surveyed linked antibiotics with sore throat treatment. However, the majority of veterinary students (63.6%) incorrectly believed that disorders of viral etiology such as colds and flu can be treated with antibiotics and there were significant differences ($P < 0.0002$) compared to the medical students’ responses. Moreover, 12% of all students stated that antibacterial drugs could be used to treat AIDS/HIV. One third of participants asserted that measles (27.3%) could be treated in the same way.

Medical students were also more certain (72.6%) that gonorrhea is a condition which is treatable with antibiotics compared to those enrolled in veterinary sciences (41.8%) ($P < 0.0001$).

To the pool of questions on the AMR awareness 94.69% of medical students responded that the human population may develop resistance to antibiotics, 4.42% claimed that it may not, and 0.88% didn’t know, compared to 82.52%, 6.31, and 11.17 of veterinary students respectively ($p < 0.0001$). Almost a half of all students strongly agreed with the statement that antimicrobial resistance can affect both the health of the respondents and their family – 47.02%, while only 1.57% strongly disagreed with that statement (table 3).

Table 3. Extent of agreement or disagreement to the statement: “Antimicrobial resistance can affect your health and the health of your family” ($n = 319$, $p < 0.0001$).

| Education | 1   | 2   | 3   | 4   | 5   | Total |
|-----------|-----|-----|-----|-----|-----|-------|
| Med       | 4   | 2   | 11  | 24  | 72  | 113   |
| % of Total| 1.25| 0.63| 3.45| 7.52| 22.57| 35.42 |
| % of Med  | 3.54| 1.77| 9.73| 21.24| 63.72|       |
| % to Vet  | 80.00| 25.00| 14.10| 30.77| 48.00|       |
| Vet       | 1   | 6   | 67  | 54  | 78  | 206   |
| % of Total| 0.31| 1.88| 21.00| 16.93| 24.45| 64.58 |
| % of Vet  | 0.49| 2.91| 32.52| 26.21| 37.86|       |
| % to Med  | 20.00| 75.00| 85.90| 69.23| 52.00|       |
| Total (%) | (1.57%)| (2.51%)| (24.45%)| (24.45%)| (47.02%)| (100%) |

The majority of all students agreed that people should only take antibiotics when prescribed by a doctor – 80.88%, while only 1.88% disagreed with that statement (table 4).

Overall, 32.29% of all respondents strongly agreed that “Antibiotic resistance is one of the biggest challenges facing by society around the world”, 26.02% – agreed, 30.41% – neither agreed nor disagreed, 8.78% – disagreed, and 2.51% of students of both categories strongly disagreed. However, medical students who fully agreed with the statement were 1.6 times more than veterinary students (43.36% and 26.21% respectively).

The majority of all students strongly agreed that everyone should use antibiotics responsibly – 93.10%, while only one veterinary student (0.31%) strongly disagreed with that statement.

Only 13.48% of students strongly agreed with the statement that an ordinary person like them does not have much influence on solving the problem of antimicrobial resistance, 19.44%
Table 4. Extent of agreement or disagreement to the statement: “People should only take antibiotics when prescribed by a doctor” \((n = 319, p < 0.0001)\).

| Education | 1 | 2 | 3 | 4 | 5 | Total |
|-----------|---|---|---|---|---|-------|
| Med       | 0 | 1 | 1 | 8 | 103| 113   |
| **% of Total** | 0.31 | 0.31 | 2.51 | 32.29 | 35.42 |       |
| **% of Med** | 0.88 | 0.88 | 7.08 | 91.15 |       |       |
| **% to Vet** | 16.67 | 6.25 | 20.51 | 39.92 |       |       |
| Vet       | 0 | 5 | 15 | 31 | 155| 206   |
| **% of Total** | 1.57 | 4.70 | 9.72 | 48.59 | 64.58 |       |
| **% of Vet** | 2.43 | 7.28 | 15.05 | 75.24 |       |       |
| **% to Med** | 83.33 | 93.75 | 79.49 | 60.08 |       |       |
| Total (%) | 0 | 6 | 16 | 39 | 258| 319   |
|           | (1.88%) | (5.02%) | (12.23%) | (80.88%) | (100%) |       |

- agreed, 34.17% – neither agreed nor disagreed, 14.73% – disagreed, and 18.18% of students of both categories strongly disagreed. There was no significant difference in the answers between the groups but it can be the evidence of crucial gaps in awareness of the environmental health integration into One Health and sustainable development.

Almost a half of all respondents (46.71%) strongly agreed with the statement that “I’m worried about how antibiotic resistance will affect my health and the health of my family”, whereas 3.13% strongly disagreed with that statement.

Responses to the statement “I do not risk facing the problem of antibiotic resistance if I take the antibiotics prescribed to me correctly” were divided: 28.21% of respondents strongly agreed with the statement, 28.53% – agreed, 26.33% – neither agreed nor disagreed, 8.78% – disagreed, and 8.15% of students strongly disagreed. There was no significant difference in answers of students in both groups.

Most of the students (70.22%) claimed that antibiotics are overused in Ukrainian agriculture, while only 3.76% didn’t think so. There was no significant difference in answers of students in both groups.

5. Discussion
This cross-sectional study among Ukrainian veterinary and medical students assessed their self-reported awareness, behavior, knowledge, and attitude towards the antibiotic usage and development of antimicrobial resistance in humans. Addressing the RQ1, preliminary assessment of compliance of the study with the global environmental health and sustainable development needs in the Dimensions.ai database revealed that the AMR awareness among medical and veterinary students is of primary concern and corresponds mostly to the SDG 2, SDG 3, SDG 12, SDG 13 and SDG 4 of the 2030 Agenda [31]. The findings correspond to the recognized SDGs that AMR can compromise sustainable development [32], with the environmental health integrated [7], but also revealed the SDG 4 (Quality Education) involvement. These findings support the need for an appropriate educational environment on the subject [15, 16, 33].

Rational antibiotic prescription and use is crucial in mitigating AMR, and dependent on knowledge and commitment of both veterinary and medical servants. In this research we carried
out preliminary assessment of awareness on antibiotic resistance among veterinary and medical students. This study is the first of a kind to assess students’ attitude to the antimicrobial resistance in Ukraine. The knowledge was determined by using multiple choice and true or false questions, covering demographic, personal antibiotic use, attitude and awareness of AMR.

The present outcome, as an answer to RQ2, demonstrated that both veterinary and medical students are aware of antimicrobial resistance issues to a certain extent, as well as its capacity to ensure environmental health as an integrated compound of One Health triad. Self-reported antibiotic usage may be considered as responsible. Most surveyed (about 70%) consulted physicians prior to using antimicrobials and almost 91% claimed that they bought the antibiotics in the pharmacy. This results corresponds to the level of awareness of target students groups in developed countries [14,34,35,36] and may indicate that whether AMR issues are embedded across curricula or this is the result of involvement in World Antibiotic Awareness Week (that medical and veterinary curricula have the effect of improving awareness of AMR). Both cohorts surveyed agreed with a high degree of confidence (86.8%; \( p < 0.0001 \)) that the human population may develop resistance to antibiotics and were quite sure (approx. 72%) that antimicrobial resistance can affect both personal health and the health of family members.

This study indicates that there are some knowledge gaps about antimicrobial usage for different pathological conditions among veterinary students. Answering the RQ3, the significant differences (\( P < 0.0002 \)) in responses was found among two groups of respondents about antibiotic prescription for treatment of disorders caused by viruses such as colds and flu, where the majority of vets (63.6%) believed that antibiotics can be used for treatment. Medical students were also more certain (72.6%) that gonorrhea is a condition which is treatable with antibiotics compared to veterinary students (41.8%) (\( P < 0.0001 \)). This may be due to different approaches to the choice of therapeutic methods in human medicine and animal husbandry. This is especially true in the prescription of antibiotics to prevent complications of inflammatory processes of viral etiology by bacterial microflora, which often happens in animal husbandry. On the other hand, it may be evidence that medical students are better trained on antimicrobial prescriptions to humans and more familiar with the protocols of treatment of different diseases of humans. Nevertheless, veterinary students have a desired level of knowledge about responsible use of antimicrobials. However, further statistical analysis is required in order to explore this question in more depth.

6. Conclusions
This study demonstrates the relationship between the antibiotic resistance issue, the Sustainable Development Goals and environmental health (RQ1), as well as represents the students’ knowledge and attitude towards antibiotics use and development of antimicrobial resistance (RQ2). Comparison of answers of medical and veterinary students (RQ3) showed that both groups acknowledged the antimicrobial resistance to a certain extent, evidencing capacity to ensure environmental health as an integrated compound of One Health triad. Differences among the responses of veterinary and medical students demonstrates that medical students are better trained on antimicrobial prescriptions to humans and more familiar with the protocols of treatment of different diseases of humans. The outcome of the survey might be used in future research, as well as in the design of preclinical and clinical courses both for veterinary and medical students with the aim to spread knowledge on the proper antibiotic use and prevention of antimicrobial resistance in order to meet sustainable development needs, address SDGs and One health approach.

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