

Antimicrobial Waste

- ERASMUS KA220-HED - Cooperation partnerships in higher education
- Project no. 2023-1-RO01-KA220-HED-000164767
- Title: Partnership for innovation on the exchange of best practices and the design of joint collaborative initiatives at European level related to the awareness of the effects of contamination on human health
- Acronym: INNO-SAFE-LIFE



Co-funded by
the European Union



Introduction to Antimicrobial Waste

Antimicrobials = drugs used against bacteria, viruses, fungi & parasites.

Widespread use in **human medicine**, **veterinary medicine**, and **agriculture**.

Improper disposal → contamination of soil, water, and air.

Growing concern → antimicrobial resistance (AMR).

Antimicrobial waste refers to leftover, expired, or excreted residues of antibiotics and other antimicrobials. These enter the environment through improper disposal or wastewater. The main concern is that they can persist, contaminate ecosystems, and drive the evolution of antimicrobial resistance (AMR), which is a global health crisis.

Understanding Antimicrobial Resistance (AMR)

AMR = microbes develop ability to resist antimicrobial drugs.

Driven by overuse and misuse of antimicrobials.

Environmental exposure to residues → major contributor.

AMR is one of the **biggest threats to public health** worldwide.

When microbes are continuously exposed to low levels of antimicrobials, they adapt and become resistant. Waste contamination creates a “background exposure” environment that accelerates resistance. WHO has declared AMR one of the top 10 global health threats.

Sources of Antimicrobial Waste

Healthcare facilities → unused or expired drugs, patient excretions.

Veterinary medicine → livestock manure containing residues.

Agriculture → pesticides, soil contamination.

Pharmaceutical industry → wastewater from drug manufacturing.

Hospitals, clinics, and households dispose of unused drugs. Animals treated with antibiotics excrete residues in manure, which enters soil and water. The pharmaceutical industry also produces contaminated wastewater. Together, these sources release large amounts of antimicrobials into the environment.



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Types of Antimicrobial Waste

- Solid waste → expired medicines, packaging.
- Liquid waste → effluents from hospitals & factories.
- Biological waste → urine, feces from humans & animals.
- Soil residues → fertilizers, manure with antimicrobial traces.

Antimicrobial waste appears in many forms. Liquid and solid waste often go untreated, leading to environmental accumulation. Biological waste is an overlooked source, as both humans and animals excrete unmetabolized drug residues.

Environmental Impact (I)

Contamination of:

Water bodies → rivers, lakes, groundwater.

Soil → long-term persistence.

Air → aerosolized particles from waste sites.

Disruption of microbial ecosystems.

When antimicrobials enter the environment, they persist in soil and water. Microbes in these ecosystems are exposed and pressured to adapt. This disrupts natural balances, harms biodiversity, and introduces resistant strains into the food chain.



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Environmental Impact (II)

Residues persist for long periods.

Act as “low-dose training” for microbes → resistance genes.

Spread of resistance via:

- Horizontal gene transfer.
- Animal-human-environment cycle.

Antimicrobial residues act like continuous micro-doses, selecting resistant bacteria in the environment. These bacteria can exchange resistance genes with pathogens through horizontal gene transfer. This makes AMR a **One Health problem** that links humans, animals, and ecosystems.

Health Risks – General Population

Resistant infections → harder to treat.

Higher morbidity & mortality rates.

Increased healthcare costs.

Reduced effectiveness of modern medicine.

As resistance spreads, infections become untreatable with standard antibiotics. This increases the severity and duration of illness, raises death rates, and costs billions in healthcare. Common medical procedures (surgery, chemotherapy) become riskier without effective antibiotics.

Health Risks – Vulnerable Populations

Children, elderly, immunocompromised most at risk.

Patients in hospitals (ICUs, surgeries).

Communities near waste disposal sites.

Farmers and workers exposed to residues.

Vulnerable groups are more likely to develop resistant infections due to weak immune systems or higher exposure levels. Populations living near contaminated environments (waste dumps, farms using manure) face higher risks of resistant pathogens.

Antimicrobial Waste Management

Proper disposal systems in hospitals & pharmacies.

Wastewater treatment for pharmaceutical effluents.

Safe manure handling in livestock farming.

Reduction of unnecessary antimicrobial use.

Effective waste management is key to reducing AMR risk. Hospitals must have systems to safely dispose of unused drugs. Wastewater treatment plants should be equipped to remove antimicrobial residues. Farmers must handle manure carefully and reduce unnecessary antibiotic use in animals.



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Global Perspectives

- AMR is a global issue → requires **international cooperation**.
- Countries differ in waste management practices.
- Need for harmonized **regulations** and **monitoring**.
- WHO & EU → frameworks for AMR reduction.

Antimicrobial waste and AMR are not limited by borders. Resistant bacteria spread globally through trade, travel, and water systems. Stronger regulations and coordinated monitoring are needed worldwide, especially in low- and middle-income countries where systems are weaker.

Role of Healthcare Professionals

Prescribe antibiotics responsibly.

Educate patients on proper disposal.

Monitor hospital waste practices.

Support antimicrobial stewardship programs.

Healthcare workers are central to solving this issue. Rational prescribing, patient education, and strict hospital waste protocols can reduce unnecessary antimicrobial release. Stewardship programs promote best practices in antibiotic use.

Public Awareness & Education

Inform communities about risks of improper disposal.

Encourage safe return of unused medicines.

Promote hygiene & responsible antimicrobial use.

Public campaigns to reduce misuse.

The public must be educated on safe disposal of antibiotics, such as returning unused medicines to pharmacies instead of throwing them in trash or drains. Awareness campaigns can also discourage self-medication and misuse.



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Research & Innovation

- New technologies for wastewater treatment.
- Development of biodegradable antimicrobials.
- Biochar, nanomaterials for pollutant removal.
- Monitoring systems for resistance genes in the environment.

Scientists are developing new strategies to reduce antimicrobial waste and resistance spread.

Biodegradable antimicrobials, biochar for soil remediation, and advanced wastewater treatment technologies are promising solutions.

Conclusion

Antimicrobial waste → serious threat to health & environment.

Drives antimicrobial resistance (AMR).

Requires action: proper disposal, regulation, education.

Collaboration across **health, agriculture, and environment sectors**.

Antimicrobial waste is a hidden but powerful driver of AMR. To protect future generations, we must act at all levels — from hospitals to households, farms to factories. A **One Health approach** uniting human, animal, and environmental health is essential to tackling this global challenge.