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Antibiotics and heavy metal resistance emergence in water borne bacteria

Abstract

Around the world is rising concern about antibiotic resistance and heavy metals contamination in water bodies because heavy metals tolerance in bacteria responsible for the proliferation of antibiotic resistance. Recently, researchers have been recognized link between heavy metal and antibiotic resistance of bacteria; similar mechanisms exist in both cases to support bacterial growth in adverse condition separately. Type of mechanisms support co-resistance pattern may be existing on same plasmid or genetic element and chromosomal materials. A number of industries and house hold activities are releasing heavy metal contaminated water, which contaminate soil and water bodies. Heavy metals are rising continuously in the water body and increasing concentration was exposed the present bacterial diversity, which develop tolerance mechanism and attaining higher level resistance to heavy metals. Whenever in future these bacteria exposed to antibiotics, then activate and express previous developed mechanisms and easily survive at high dose. Antibiotics and heavy metals resistance emergence in waterborne bacteria has potential significance in environmental, clinical research and drug development.

Keywords: waterborne, bacteria, antibiotics, heavy metals, resistance

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Introduction

Microorganisms are important and omnipresent in nature, involved in directly and indirectly in most of the biological process of living being. Modernization is increasing with industrialization, urbanization and changing lifestyle which ensuring antibiotics and heavy metals increasing amount in microbial habitat. In general metals and minerals play significant role in metabolic activities and cell formation and reproduction.[1] Recently, in human being lifestyle diseases are increasing the consumption of antibiotics also enhances and released a huge amount of un-metabolized drugs in sewage which contaminate water bodies several other anthropogenic activities increasing the antibiotics and metals concentration in water bodies. Increasing concentrations of both antibiotics and metals beyond the tolerance limit create an evolutionary force of adaptation in harsh environment. These heavy metals and antibiotic stress are attaining a modification in the genetic makeup of chromosomal and plasmid DNA of bacteria, which occurred by genetic mutation and genetic elements transfer from the resistant bacteria in the surrounding environment. For metal tolerance bacteria developed mechanisms like efflux system, precipitation, complexation, accumulation and reduction of metal ion and in anaerobic respiration terminal electron acceptor in metal.[2] In many reports heavy metal tolerance was observed in a number of bacteria and it has been recognized plasmid born resistance gene like antibiotic resistance. These plasmids borne mobile resistance gene easily transfer and spread in bacterial population through the efflux system and carry in next generation.[3,4] If both genes available on a plasmid, it might be determined by plasmid curing experiment. Antibiotic and heavy metals resistance gene present together has been observed on the same plasmid.[5] Potentially pathogenic bacteria are continuously coming in, water bodies from the hospital and sewage water, which may contain a mobile genetic element like plasmids, interns and transposon. These transferable genetic elements are able to transfer horizontally in other non-pathogenic bacteria, further these non-pathogenic bacteria became pathogenic or virulent due to acquired resistance to multiple antibiotics.[6] Genetic elements like plasmid, transposing and integron mediated antibiotic resistance gene transfer has been found frequently, especially in medical isolates.[7,8] Likewise, antibiotic resistance can be co-selected with metals tolerance. When bacterial isolates of *Pseudomonas aeruginosa* was exposed to a small concentration of zinc, then induce resistance against imipenem, mechanistically OprD porin gene repressed which prevent the influx of the antibiotic.[9,10] Similarly, researcher found that copper was able to induce imipenem resistance in bacteria.[11] These findings suggested that the metal ions found in hospital discharge or settings can contribute or take part, in the emergence of antibiotic resistance. Because antibiotic and heavy metal resistant genes are to be found in some mobile genetic element, metal pollution frequently promotes antibiotic resistance emergence in exposed microorganisms that also has a growing concern in ordinary and clinical settings.

Heavy metal resistance emergence in water borne bacteria

Most of the Heavy metals like cobalt, copper, chromium, manganese, nickel, and zinc in trace amounts are essential for metabolic activities and growth of microorganisms. Whenever concentrations increase then threshold levels they have deleterious effects on various organisms. While some other heavy metals cadmium, mercury and lead have no biological role, and at very low concentrations have a disadvantageous effect on microorganism. Most of the industrial discharge contains a huge amount of heavy metals which contaminate nearby water bodies and continuously increasing concentration of metals which exposed to present microorganisms in water bodies. These slowly increasing concentrations of toxic metals developed resistance against it. Heavy metals environment inhibiting bacteria have developed additional strategies to save from cope up of higher concentration stress. Resistance to heavy metals can be conferred by mobile genetic elements or chromosomal and acquired adaptations strategies like

i. Efflux metal ion from outside of membrane,

ii. Accumulation and complexation of metal ions inside or between the cell membrane

iii. Reduction of oxidation state of metal ions

iv. Mutation of cellular target factors and

v. Enhance exopolysaccharide production to bind metal ion outside the membrane overall metal resistance activities similar to antibiotic resistance.

Emergence of metal-antibiotic co-resistance in bacteria

Co resistance is defined as the existence of for two or more tolerant/resistance genes on one mobile genetic element. Co-existence of both heavy metals and antibiotic resistance genes founds in numerous environments like gastrointestinal tracts, soil, water, animal manure and poultry farm sites.[12,13] Organisms are accumulating heavy metals inside inclusion bodies and organs because heavy metals are persistent material unable to degrade and convert other forms except oxidation state.[14] However, a number of antibiotics are observed like pseudo-persistent, continuously they are coming into the ecosystem through different processes.[15,16] In many natural environments containing microbial communities, the emergence and further spread of antibiotic resistance and even multidrug resistance in bacteria is observed due to co-contaminations of heavy metal and antibiotics.[17,18] For example, in activated sludge bioreactors, co-exposure to Zinc (Zn) and antibiotic (Oxytetracycline) appears to enhance the drug resistance of the bacterial community.[19] Agricultural soils amended with Copper (Cu) for co-selects resistance to antibiotics like ampicillin, chloramphenicol and tetracycline.[20] Exposure of microcosms to metals like Nickel (Ni) and Cadmium (Cd) enhance the chance of bacterial resistance to antibiotics including Ampicillin.[21] This phenomenon of enhanced resistance can be attributed to the presence of heavy metal that increased the enrichment and growth of indigenous bacteria in the bacterial community, that are previously having drug resistance genes. On the other hand, resistance in antibiotic sensitive bacteria could be imported due to the coexistence of heavy metals and antibiotics in the environment. Therefore, positive correlation is existed between the abundance of heavy metals tolerant genes and increased concentrations of both heavy metals and antibiotics in environments as reported by several workers.[12,22] Genetic elements like integrons that exist within transposons, contain genetic resistance determinants they transfer with a larger element with integral elements. Transposon (Tn21 and Tn21) is the most studied in connection with co-resistance. Both have Hg-resistance operon and an integron which responsible for multiple antibiotic resistance genes in an organism.[23,24] In evolutionary history, Tn21 was identified as the acquisition of the integron In2, to acquire antibiotic-resistance genes for streptomycin and spectinomycin.[25] In *Enterococcus faecium* Hg-resistance operon was situated within transposon, it was also found in a conjugative plasmid which streptomycin resistance.[26] Transposons play a key role in co-resistance and co-selection of drug and heavy metal tolerance and these linkages are important for medical and environmental bacterial diversity. In general, many studies have shown that pathogenic and non-pathogenic bacteria contain both Tn21 and Tn21-like transposons.[23,24,27]

Significance

The emergence and spread of antibiotic resistance genes and their acquisition by pathogens is associated with the increased morbidity and mortality. The unabated use of antibiotics in both human and veterinary settings along with the release of clinically relevant antibiotic resistance genes and antibiotic resistant bacteria as a result of human activities has currently become a major environmental issue. However, the risk assessment models employed currently to determine the effect of antibiotics and antibiotic resistance genes on the emergence and selection of resistance are still inadequate. As oppose to chemical contaminants and pollutants that are degradable, bacteria are persistent and are capable of multiplying and spreading in the environment. Drug resistance genes carried by these bacteria proliferate in their hosts, can be transferred to other bacterial populations through various mechanisms and are subject to evolution. This transfer of resistance genes from one population to another is a major issue in controlling infections and preventing health hazards.

Conclusion

Agriculture and aquaculture influenced soil and water environments are greatly affected by heavy metals such as Cd, Hg, Cu, and Zn. These metals demonstrate varying levels of toxicity to bacteria of soil and water. These metals enter the environment, persist and accumulate to selective concentrations causing environmental pollution and health hazards. In addition to the contamination of soil and water environment, they also initiate the co-selection of antibiotic resistance using mechanisms discussed earlier. Further, comprehensive account of the mechanisms associated with the acquisition and dissemination of drug and metal resistance needs to be studied. Simultaneously, to prevent evolution and spread of resistance, effective risk assessment models and management plans need to be implemented urgently to impose checks against dissemination of resistance genes and protecting human health and the environment in general.

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Conflict of interest

Author declares that there is no conflict of interest.

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