Backgrounder: Metrics and Indicators for Measuring and Reporting on Antimicrobial Use in Animals

What are antimicrobial use metrics and indicators?

An antimicrobial use (AMU) *metric* is a measurement of the amount of antimicrobial used or the frequency of antimicrobial use.

An AMU *indicator* is a metric in relation to a denominator.

AMU metrics and indicators are used to better understand AMU and antimicrobial resistance (AMR). Common uses in animal sectors include: A) to describe the current level of AMU within a farm, or within a production type at a local, regional or national level; and B) to describe AMU trends over time.

In planning reporting of AMU in animals, *indicator alignment* and the *benefits of using multiple indictors* are important considerations. Aligning AMU metrics and indicators within and between sectors increases opportunities for information integration and trend analysis. Using multiple AMU indicators in reporting provides richer and more detailed information and reduces the risk of inaccurate interpretation. The purpose of this document is to provide a background on AMU metrics and indicators in order to guide further work aimed at aligning metrics and indicators within and between animal sectors and improving overall reporting of AMU in animals in Canada.

Metrics and indicators used for measuring and reporting AMU in animals can be grouped into three broad categories;

- count-based,
- weight-based and
- dose-based.

Within each main category, different approaches to measurements and calculations, along with differences in the production systems for various animal types, result in multiple different metrics and indicators, each with their own advantages and disadvantages. The tables below describe the three categories, summarize strengths and weaknesses of each category, and provide examples of how each has been used in AMU reporting in Canada and internationally.

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Table 1. Categories of indicators for measuring and reporting AMU in animals

	Count-based	Weight -based	Dose-based
Numerator (Metric)	Number of farms treated *Or* Number of animals treated *Or* The number of antimicrobial (AM) products or medicated rations *Or* Number of days on medication	Weight (mg) of active ingredient used	Number of 'defined daily doses' used
Denominator	Total number of farms in the population *Or* Total number of animals in the population *Or* Number of total days in production cycle/phase	kg animal biomass = population x kg live weight (OIE formula) *Or* Population Corrected Unit (PCU) = population x average weight at treatment (ESVAC) *average weight may vary by jurisdictions (e.g. European vs Canadian)	Number of individuals in the population *Or* Animal-time (length of time a population of animals was at risk of being exposed to the AM e.g., number of days of that stage in production cycle) *Or* PCU
Examples	Proportion of animals with medicated feed rations Proportion of days on treatment Proportion of farms exposed/ at risk over a defined time period Proportion of animals exposed/ at risk over a defined time period	mg AI (active ingredient)/kg animal live pre-slaughter (poultry) mg AI/PCU (Population Corrected Unit) mg of AI (active ingredient)/kg feed consumed mg AI/1,000 animal days	DDDvetCA[1]; DCDvetCA[2] [Defined daily dose; poultry; pigs; injectable, feed, water] ADDpig[3] [Animal daily doses; swine; injectable, feed, water] AB_{100}[4] (expresses AMU as a % of days of treatment for animal types receiving medication at a group level)
Uses	description of use in a single production type benchmarking between farms of a single production type Trends in above over time	comparison of use between farms, production-types or veterinarians Trends in above over time	comparison of use between different antimicrobials, animal types and regions Trends in above over time
	Count-based	**Weight -based**	**Dose-based**
Advantages	Easy to calculate and understand Can be combined with weight-based metrics to tell a story	Relatively easy to understand Expresses AMU in terms of mg active ingredient per kg of animal produced (depending on denominator used) Adjusts for both the number and weight (biomass) of animals in the population Change in animal biomass will not alter the trends as long as consistent weight is used	Expresses AMU in terms of the weight of biomass treated per kg of animal (interpretation is based on the denominator) Only method that accounts for the fact that different AMs are dispensed at different mg/kg doses (differences in potency) Adjustment for dose will yield a much better measurement of change in AMU practices, e.g. 1 kg of tetracycline does not have the

[1] Bosman, A., Loest, D. Carson, C., Agunos, A., Collineau, L., Léger, D., (2019) 'Developing Defined Daily Doses for Animals: A Metric to Quantify Antimicrobial Use' *Frontiers in Veterinary Science* Vol. 6, Article 220

[2] Ibid

[3] McLaren-Almond, C (2019) 'Antimicrobial Use in Ontario Swine Nurseries' *The Atrium University of Guelph* pp. 34-39, 57-58

[4] Étude de faisabilité pour un système de monitorage des antibiotiques en santé animale au Québec, Cécile Ferrouillet, 26 mars 2021

			same selection pressure as a 1 kg of enrofloxacin. Provides standard doses that can be used to facilitate standardized measurement of AMU
Disadvantages/ Cautions	Does not allow comparison across animal types, types of production. Does not allow accurate AMU comparison across antimicrobials because different AMs are prescribed at different mg/kg doses	Does not allow accurate AMU comparison across antimicrobials because different AMs are prescribed at different mg/kg doses In production types with <1 year There is approximation of standard body weight, so this may be inaccurate	Can be challenging for non-experts to understand Standardized doses for each antimicrobial (AM) are used in calculations. These technical standards may differ from 'real world' dosing practices. Extra-label drug use (ELDU) is not accounted for. Does not reflect differences in ELDU across regions
Used by	Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) in broiler chicken, turkey and grower-finisher pigs	CIPARS in broiler chicken, turkey and grower-finisher pigs	CIPARS in broiler chicken, turkey and grower-finisher pigs

Table 2. Explanation of methods of reporting animal weights in weight-based metrics

Biomass	**Population Corrected Unit (PCU)**
Number of animals at risk multiplied by a previously agreed on *average weight at treatment* for that production phase. The concept of assigning the standard weight to form a biomass denominator as the average weight at treatment is under review by certain countries, an alternative being the average weight at the end of grow-out, e.g. slaughter weight.	The population at risk of being treated is approximated by the number of individuals at risk of being treated multiplied by a standard body weight at treatment.

Table 3. Dose-based metrics used in Canadian AMU/AMR surveillance

	Example	Advantages	Disadvantages
AB_{100}[2] = Total AM (mg)/DDDvetCA (mg/kg/day) ---------- X 100 total animals x standard weight (kg) x days at risk	The AB_{100} of amoxicillin is: [80 million/16 (mg/kg/day)]/ 800 pigs x 100kg x 100 days = 0.625 X 100 = 62.5	Expresses AMU as a % of days of treatment for production types treated as a group; uses 100 rather than 1000 animal days to ease interpretation Calculated by month and year rather than batch or lot Intended to be used in poultry and swine Animal days at risk based on databases available of # of animals on the farm during the year; adjusts for periods when not in production	Not intended for livestock receiving individual doses
DDDvetCA[3] (Defined Daily Dose - assumed average dose per kg animal per species per day). Involves determining the average of all unique doses for each AAI (antimicrobial active ingredient) across all authorized products for use in the species of interest, by route of administration DCDvetCA[1] (Defined Course Dose per animal/course) ADD[3] – Animal Defined Daily Dose (national defined average maintenance dose per day per kg animal of a drug in a species or the dose needed to treat one animal of a given size for one day for the main indication)	DDDbovCA[4](Defined Daily Dose for cattle in Canada [mg (or g)/animal per day]) The DDDvetCA of amoxicillin for pigs is 16 mg/kg of pig/day administered through water. The DDDvetCA for a pig weighing 100kg is 1,600mg/day. DCDbovCA[2](Defined course dose for cattle in Canada): mg (or g)/animal per course	Provides standard doses that can be used to facilitate standardized measurements of AMU. Provides a fixed unit of measurement independent of formulation and potency.	Approximation of: - standard body weight - average daily food/water intake - average animal (e.g., age, weight, other) targeted by the label - duration of action for long-acting products Standard Canadian dose definitions need to be established to compare DDDs/DCDs across studies and must remain consistent for data to be useful over time. Gives a statistical measure for comparing AMU and not an exact picture of actual use. Extra-label drug use is not accounted for.
nADD[4](number of Administered Daily Doses) Quantity of active ingredient (mg) administered/ADD (mg/kg/day) x weight (kg) of animal	An average beef cow weighs 400kg. An average dose of injectable oxytetracycline is 10mg/kg. 50 kg of		Not useful for comparing AMU across AMD classes or between animals of different weights

[2] Étude de faisabilité pour un système de monitorage des antibiotiques en santé animale au Québec, Cécile Ferrouillet, 26 mars 2021

[3] Bosman, A., Loest, D. Carson, C., Agunos, A., Collineau, L., Léger, D., (2019) 'Developing Defined Daily Doses for Animals: A Metric to Quantify Antimicrobial Use' *Frontiers in Veterinary Science*
Vol. 6, Article 220

[4] Larde, H., Dufour, S., Archambault, M.,Léger, D., Loest, D., Roy, JP., Francoz, D., (2020) 'Assignment of Canadian Defined Daily Doses and Canadian Defined Course Doses for Quantification of Antimicrobial Usage in Cattle' *Frontiers in Veterinary Science* Vol. 7 Article 10

[3] McLaren-Almond, C (2019) 'Antimicrobial Use in Ontario Swine Nurseries' *The Atrium University of Guelph* pp. 34-39, 57-58

[4] Brault, S., Hannon, S., Gow, S. Otto, S., Booker, C., Morley, P., (2019) 'Calculation of Antimicrobial Use Indicators in Beef Feedlots – Effects of Choice of Metric and Standardized Values' *Frontiers in Veterinary Science* Vol. 6 Article 330

	Example	Advantages	Disadvantages
	oxytetracycline were given to beef cows in a region. Therefore the nADD for oxytetracycline in the region is 12,500		
ADUR[1] (Antimicrobial Drug Use Rate) ADD/1,000 cow-days): used for dairy cattle; systemic, intramammary, topical, oral, uterine]	Active ingredient used in the study period (g) 1,000 cows/ADD × number of days in the study period. For example, the ADUR of penicillin across 89 Canadian dairy farms was 2.56 g from 2007-2008 (10,421 ADD/1,000 cow days)	Corrects for differences in therapeutic potency of active ingredients and formulations of drugs Adjusts for length of time animal or group of animals are treated	Assumes AMU is as per average on-label recommended dose and does not consider extra-label drug use (ELDU). If ELDU varies between regions, would not reflect these differences. Does not distinguish between treatment protocol. For example, 1 to 2 syringes per cow in 24 hr for mastitis and 4 tubes per cow for dry cow therapy – both protocols constitute one ADD.
UDD[2] (Used daily dose) - [Used Daily Dose or actual administered dose per day per kilogram pig of a drug within a herd [actual administered dose/day/kg]; any administration route]	Example: 8 mg/day/kg pig tetracycline administered by water.	Reflects actual administered dose/day/kg	Specific to the population at that point in time Is not equivalent to a DDD which is a technical unit of measure; also different from the PDD or Prescribed Daily Dose Requires detailed data, including used doses and animal weights at treatment
TI[2] (Treatment incidence - any indicator of use with an animal-time denominator is a treatment incidence.) Studies in sheep, swine; any administration route.	Number of animals out of a theoretical group of 1000 animals received daily AM treatment or, if one animal would live for a theoretical period of 1000 days, how many of these days it would have been treated with an antimicrobial. UDD of 16 mg/kg amoxicillin x 1,000 days x 50,000 kg (1,000 pigs x 50 kg each) TI = 800 million [Total amount of active substance administered	Reflective of actual treatment	Accounting for the numbers of individual animals treated causes divergent results in benchmarking

[1] Saini, V., McClure, J.T., Léger, D., Dufour, S., Sheldon, A.G., Scholl, D.T., Carkema, H.W., (2012) 'Antimicrobial Use on Canadian Dairy Farms' *Journal of Dairy Science* Vol. 95 No. 3

[2] McLaren-Almond, C (2019) 'Antimicrobial Use in Ontario Swine Nurseries' *The Atrium University of Guelph* pp. 34-39, 57-58

	Example	Advantages	Disadvantages
	(mg)/ADD pig or UDDpig (mg/kg) x number of days at risk (or observation period (days) x kg animal at risk (1,000 animals at risk)]		

Prescribed vs. Dispensed vs. Used

Prescribed	Amount of a specific antimicrobial drug to be administered to a specific animal patient or group of animals, via an appropriate route of administration, at a defined frequency and for a specified duration in order to treat or prevent an identified disease, as directed by a licensed veterinarian.
Dispensed	Amount of a specific antimicrobial drugsupplied or sold to the animal caretaker for use in a specific animal or group of animals, as part of (but not necessarily the entirety) of a veterinary prescription.
Used	Actual amount of a specific antimicrobial drug administered to a specific animals or group of animals, including extra-label drug use, which may be part or the entirety of the amount of drug dispensed.

Caution: Comparing AMU across production sectors

1.	Attempting to directly compare antimicrobial use across production sectors can be challenging. Antimicrobials are administered to different animal types for varying reasons. Key metrics that are meaningful for a certain sector or animal type may not be useful for another. For example, count-based metrics used for poultry are useful for observing AMU trends over time within poultry, but using count-based metrics for measuring AMU in pigs is not useful without putting the use data into a biomass calculator.
2.	Using weight-based metrics for a species that grows significantly over the production cycle like swine or cattle can be problematic. Finfish for example, have a huge weight range over the production cycle, with brood stock generally weighing 30-40lb and hatchery fish weighing as little as 100 – 150g. In addition to this, the finfish production cycle ranges from 32-52 months. The variation in weight, duration of production cycle, and varying environments over the production cycle present challenges for comparing AMU indicators across animal and production types, and creates a significant risk of inaccurate or biased conclusions.
3.	In production types with <1 year production cycle, it is important to clearly describe the reporting period (annual or production cycle) and the rational for the chosen time period. Where annual time period is used, it is important to describe that measurement is a proxy at population level rather than a measurement of actual exposure for every individual or batch.[1]

[1] O'Neill, L., da Costa, M., Leonard, F., Gibbons, J., Calderon Diaz, J., McCutcheon, G., Manzanilla, E., (2020) 'Does the Use of Different Indicators to Benchmark Antimicrobial Use Affect Farm Ranking?' *Frontiers in Veterinary Science*, Vol. 7 Article 558793