WHONET

DHIS2

WHO Collaborating Centre for Surveillance of Antimicrobial Resistance

Boston, December 2022

WHONET – Getting Started

This tutorial includes the following sections.

Part 1. What is DHIS2?

As described on the DHIS2 website, www.dhis2.org:

> *DHIS2 is an open source, web-based platform most commonly used as a health management information system (HMIS). Today, DHIS2 is the world's largest HMIS platform, in use by 73 low and middle-income countries. Approximately 2.4 billion people live in countries where DHIS2 is used. Including NGO-based programs, DHIS2 is in use in more than 100 countries.*
>
> *DHIS2 software development is a global collaboration managed by the Health Information Systems Programme (HISP) Centre at the University of Oslo (UiO). HISP is a global network comprised of 17 in-country and regional organizations, providing day-in, day-out direct support to ministries and local implementers of DHIS2.*
>
> *To learn more about the capabilities of the DHIS2 software platform, visit our DHIS2 features overview page at https://dhis2.org/overview.*

Below are two examples of DHIS2 dashboards which convey some sense of the analytical and display features of the DHIS2 platform.

DHIS2 is widely used to support many public health surveillance and program operational needs including infectious disease surveillance, mother and child health (antenatal care, deliveries, vaccination schedules), logistics (ICU bed and ventilator availability), among many other valuable applications, especially at national level.

Users are free to create their own DHIS2 platforms or alternatively utilized and customize standard multicomponent packages, such as the below which have been co-developed and validated by WHO and DHIS2 coordinators.

Community Health Information Systems
Reproductive, Maternal, Newborn, Child and Adolescent Health (RMNCAH)
Nutrition
Expanded Programme on Immunization
Civil Registration and Vital Statistics (CRVS) & Mortality
Integrated Disease Surveillance
HIV
Malaria
Tuberculosis (including TB Drug Resistance)
COVID-19 Surveillance
COVID Vaccine Delivery

Unfortunately, at this time there are no standardized DHIS2 modules for the management of antimicrobial resistance (with the important exception of the narrowly focused TB Drug Resistance Survey Tracker). A few groups are working on this, including the University of Oslo and the WHONET Team at the WHO Collaborating Centre for Surveillance of Antimicrobial Resistance among others.

While DHIS2 can be installed on local laptops or desktops within a healthcare facility, the most installations of DHIS2 are managed at the national level on web servers hosted by the Ministry of Health or Cloud service providers such as Amazon Web Services (AWS). Options recommended by DHIS2 can be found at: https://dhis2.org/hosting.

Part 2. Getting started with DHIS2 – Available resources

It is not possible within this tutorial to provide a thorough overview of DHIS2 features and implementation requirements, but DHIS2 does provide a large number of training opportunities and resources. DHIS2 support strategies recognize four broad categories of system needs. The primary focus of this tutorial is on DHIS2 "Users".

- Users: One may recognize various categories of system users according to the designated rights conferred to specific user roles at the facility, subnational, and/or national levels. Responsibilities may be limited to data entry and/or data analysis. Higher-level "manager" users may also be granted to relevant aspects of the DHIS2 "Maintenance" application such as creating of data elements, managing dropdown lists and organisation units, and data imports. Extensive knowledge of the DHIS2 backend and system maintenance is not required.

- Implementers: Implementation managers require sufficient knowledge of DHIS2 requirements, concepts, and data models to translate health project operational and reporting requirements into a successful implementation plan. A key aspect is elaborating the data management strategy (working with project stakeholders to define data content, analysis, and reporting needs), while another is the project management plan (staffing, service contracting, resource allocation, timelines).

- Administrators: These are typically web database management staff responsible for system installation, configuration, monitoring, backups, and support to daily operations and server management.

- Developers: DHIS2 offers a broad range of core features available within all DHIS2 implementations. However, recognizing the limitations of DHIS2 core functionality and the very specific data management needs of specific implementations, it is possible to develop new software applications compatible with the DHIS2 data management system utilizing the DHIS2 backend database and Application Programming Interfaces (API) functions offered by DHIS2.

Some useful links for learning more about DHIS2 and DHIS2 certification courses include the following:

- DHIS2 Home page https://dhis2.org
- DHIS2 Documentation https://docs.dhis2.org
- DHIS2 Academy https://dhis2.org/academy
- DHIS2 Training https://training.dhis2.org
- DHIS2 Community https://community.dhis2.org
- DHIS2 App Hub https://apps.dhis2.org
- DHIS2-WHO Packages https://dhis2.org/who

For use with this tutorial, we can recommend testing on the DHIS2 Demo website. This implementation is reinitialized by the University of Oslo on a nightly basis, so the user can freely explore the WHONET-DHIS2 features described here with no concern about "breaking the system".

- DHIS2 Demo website. Username is "admin" and password is "District1#" https://play.dhis2.org/2.37.3/dhis-web-commons/security/login.action

Part 3. DHIS2 Data Models

DHIS2 supports three primary data models, each of which are relevant for antimicrobial resistance surveillance.

1. **Data Sets** for aggregated data. For the first two decades of DHIS development, the focus was on the collection and management of aggregate statistics, such as the weekly "Number of cases of malaria", "Number of live births", and "Number of BCG vaccinations provided" from a particular health center. Such aggregate statistics are defined as "Data Sets" within DHIS2 terminology.

2. **Event Programs** for individual case or event monitoring. Recognizing the success of DHIS for the management of aggregated data, there was increasing recognition of the need to collect more granular case-based data where information on individual patients, medical visits, or deliveries could be provided. For example, rather than entering the total number of cases of malaria, individual information is entered for each case, including patient name, date of the visit, microscopy result, and therapy.

3. **Tracker Programs** for individual patient tracking over time. While "Event Programs" significantly improved the richness of data over aggregate Data Sets, they had deficiencies with regards to tracking patients over time with repeated medical visits. For example, in an Event Program one may determine that there were 100 cases of malaria in a year, but without knowing how many individual patients had malaria recognizing that some individuals may have had malaria more than once. DHIS2 Tracker Programs solve that through the use of unique patient identifiers to define) and a data model that supports tracking individuals ("Tracked Entity Instances" = TEI) over time and across distinct healthcare services. For example, a woman can simultaneously be enrolled in multiple services such as antenatal care, tuberculosis treatment, and COVID vaccination. Tracked entities can also have "relationships", such as parent, household member, or COVID contact.

Each of these models would be relevant for antimicrobial resistance depending on concerns such security of patient details, data complexity, data volume, performance, and most importantly intended use of the information.

- Data Sets are the simplest type of data with the lowest demands in terms of data management and security. For example, one simply may indicate that there were 35 isolates of *Escherichia coli* in a clinic in a single month and that 20 of these (57%) were resistant to ampicillin, providing no confidential patient-level details such as name or date of birth. Such aggregate statistics are of great value to clinicians and policymakers, avoiding the legal and security obstacles to collecting protected health information (PHI).

- Event Programs: It is possible manage "patient-level" or in a microbiology "isolate-level" detail. One can enter confidential patient information if that is desired, but since DHIS2 cannot track individual patients with Event Programs, confidential details can be omitted if there are security concerns. Event programs offer much richer and flexible reports as selection criteria can be defined at the

time of data analysis, whereas for Data Sets, one can only analyze the aggregate statistics which have been entered restricting the types of *ad hoc* analyses that would be possible. Event programs permit a range of *ad hoc* data filters, data stratification levels, and comparisons of relevant variables, such as comparing gentamicin resistance with amikacin resistance. Utilizing DHIS core functionality, one cannot remove "repeat isolates" from the data analysis, which can bias resistance estimates, often to higher rates since patients with multiple samples are commonly hospitalized patients with lengthy stays and antimicrobial courses with higher proportion of resistance. But in a low-resource setting, the frequent of "repeat isolates" is relatively low, so resistance estimates should still be meaningful.

- Tracker Programs: Tracker provides the greatest flexibility, including the recognition of repeated isolates from a single person. However, with DHIS2 core functionality there are still limitations. The standard DHIS2 data analysis application have the ability to find "the most recent organism" finding but cannot identify the "first isolate per patient of a particular species". For samples and for patients, DHIS2 core features cannot selectively analyze the specific findings desired by the data analyst.

In this tutorial, we present the export of aggregate "Data Sets" and isolate-level "Events" from WHONET to DHIS2. The University of Oslo is far-advanced in the development of a "Tracker Program" for the management of antimicrobial susceptibility test results, which is not covered in this tutorial.

Part 4. WHONET Strategy for DHIS2 integration

Generally speaking, there are two common approaches for introducing a new DHIS2 implementation:

- Manual configuration: After establishing the data entry and analysis specifications, the user manually enters the needed implementation "metadata" such as DHIS2 "category options", "data elements", "data sets", "programs", "dashboards", and other relevant features into the DHIS2 "Maintenance" application.

- Standard DHIS2 packages: DHIS2, WHO, and others have collaborated on a number of priority "Data Set", "Event", and "Tracker" implementation packages, developed, optimized, and validated by experts in collaboration with pilot sites. All of the needed DHIS2 "metadata" are preconfigured within standard distribution packages available on the DHIS2 website. Periodic updates to the standard packages are generally required as new data requirements are identified and system features expanded.

In our strategy to integrate WHONET with DHIS2, we did not want to suggest a manual approach as being overly tedious to users and subject to errors and incompatible installations. We also elected not to use pre-defined implementation packages, as they are also rigid with regards to data content. This leads to problems of incompatible local

adaptations of the official packages and introduces problems with long-term maintenance as project needs expand.

Because of the limitations cited, in WHONET we took a different approach which we believe to be more convenient for users, more standardized across installations with divergent needs, more flexible with regards to local configuration needs, and more suitable for long-term maintenance. In this approach, the needed DHIS2 metadata are generated at the same time as every WHONET data export.

In the WHONET approach, if a WHONET data set has results from 50 pathogens, 30 antimicrobials (25 by CLSI disk diffusion and 5 by CLSI MIC), 40 specimen types, and 30 local locations, WHONET will automatically prepare a metadata file which corresponds exactly with the data needs of that export. Each data item will have a unique "hashed" universal identifier (UID) that will be consistently generated with subsequent exports and from different WHONET-DHIS2 installations. As additional organisms, antimicrobial tests, specimen types, and locations are added in the future, consistent DHIS2 UIDs will be generated automatically by WHONET.

The WHONET approach is thus similar to the strategy utilizing standard pre-defined DHIS2 metadata installation packages from the DHIS2 website, but where the metadata package is generated by WHONET in real-time according to the specific local user configuration and data entered.

- Step 1. Configure WHONET and enter data manually or import existing data files using BacLink, WHONET's data import utility
- Step 2. Use WHONET for the simultaneous export of WHONET analysis results or isolate listings to data files and accompanying metadata files
    - Metadata are exported in DHIS2 JSON format
    - Aggregate statistics are exported to DHIS2 Data Sets in DHIS2 CSV format
    - Isolate-level records are exported to DHIS2 Events in DHIS2 CSV format
- Step 3. Use the DHIS2 to import the metadata
    - Use "Import Metadata" to import the DHIS2 JSON metadata file
- Step 4. Use the DHIS2 to import the data
    - Use "Import Data Set" to import the aggregate statistics "Data Sets"
    - Use "Import Events" to import the isolate-level "Events"

Steps 2, 3, and 4 are described further in the below sections. For Step 1, "WHONET – Getting started" and "BacLink – Getting started" are useful introductory resources for those new to WHONET.

Part 5. Exporting data from WHONET to DHIS2

At the present time, WHONET offers three possibilities for exporting data to DHIS2:

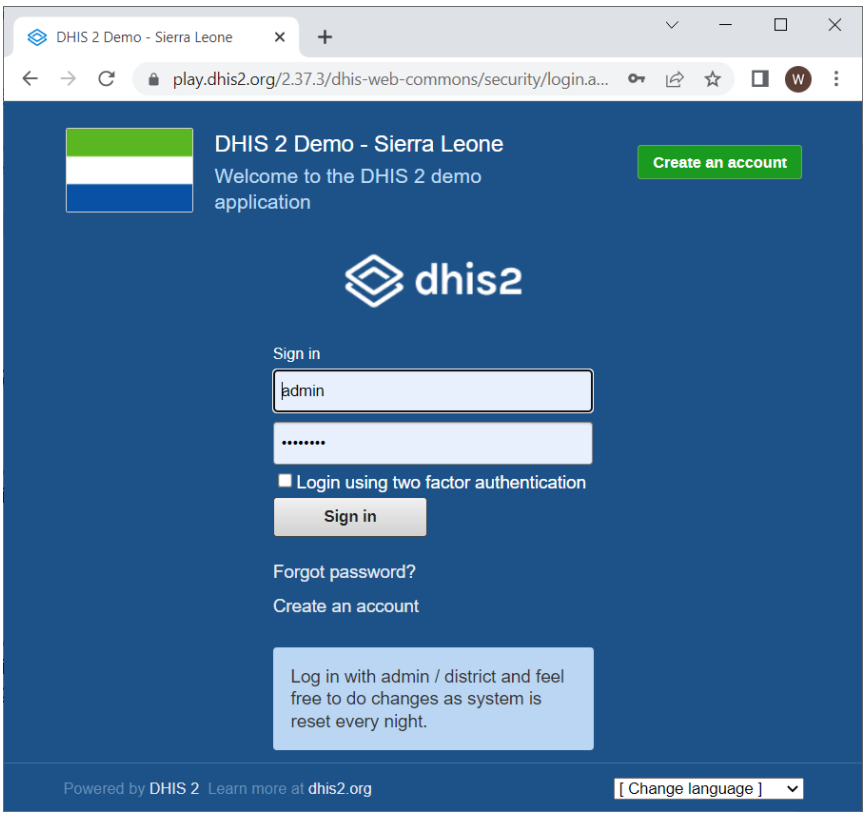
- WHONET-DHIS2 standard report, available for WHONET "Quick analysis"
- WHO GLASS sample and antimicrobial statistics from the "Combine, export, or encrypt data" menu
- User-defined *ad hoc* interactive exports available through the usual WHONET "Data analysis" menu

5.1 Finding the DHIS2 Organisation Unit UID

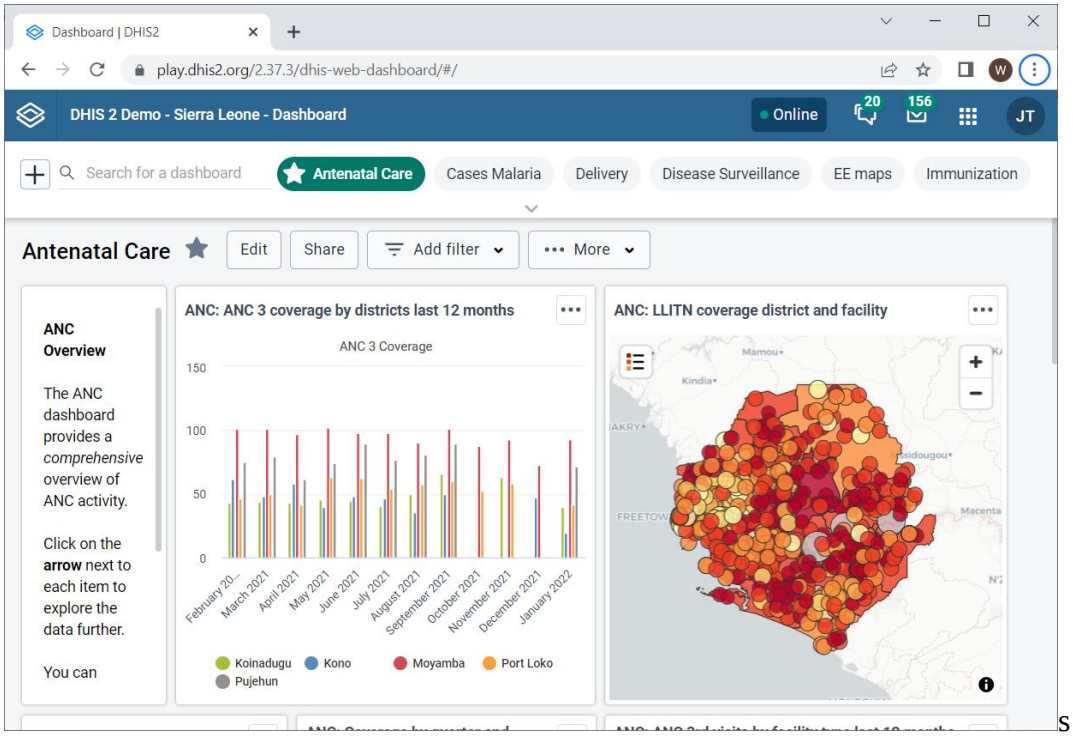
Before exporting data from WHONET, there is one important detail that the user must find within DHIS2 to get started. To import data into DHIS2, DHIS2 needs to know the unique identifier (UID) for the "Organisation Unit" below which the user wants to import the data. Typically, this would be the UID for the top-level Organisation Unit, such as "Country".

The below steps describe how to find the UID for the Organisation Unit using the official DHIS2 Demo site as an example.

- Enter your DHIS2 website. If you have no DHIS2 website yet, you can use the below link for the official DHIS2 Demo website to practice. https://play.dhis2.org/2.37.3/dhis-web-commons/security/login.action

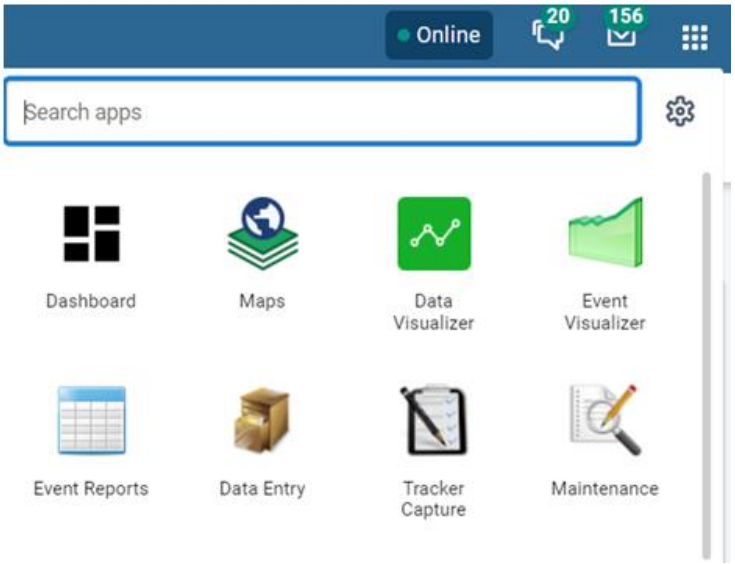


- Log in. For the DHIS2 Demo website, the username is "admin", and the password is "District1#", as indicated on the webpage. You will then see a screen similar to the below. The county depicted in the DHIS2 Demo is Sierra Leone.

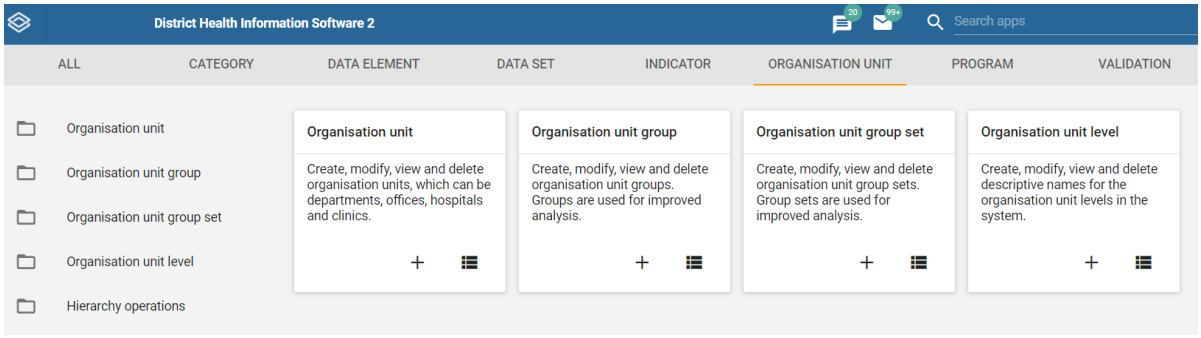


- In the upper right-hand corner of the screen, you will see an icon with nine small squares organized into the shape of a square, as seen below to the left of “JT”. This is the link for the DHIS2 applications menu.

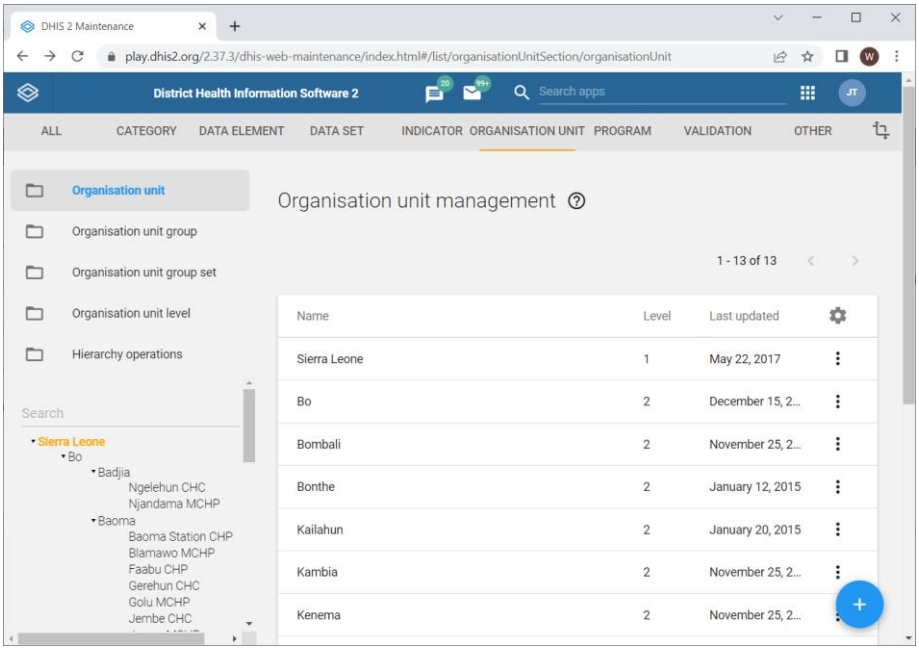
- Click on this icon to see the below menu. An icon for the “Maintenance” application is visible on the second row. If you do not see this icon, you can also use the “Search” feature.



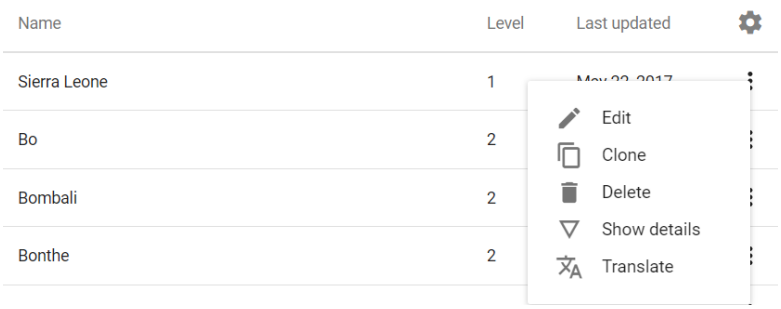
- After clicking on the “Maintenance” icon, select “Organisation Unit” from the menu to see the below.



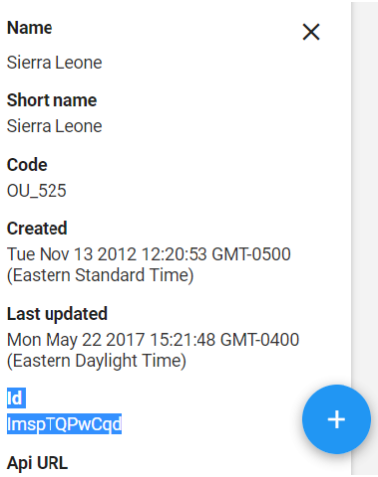
- In the lower right-hand corner of the “Organisation unit” tile, you see two symbols. The first (“+”) is used to create new locations. Click on the second “List” icon to see a list of locations defined, as below. The country name “Sierra Leone” is defined as the top-level Organisation Unit (Level 1). In Sierra Leone, Level 2 is the “District”, Level 3 is the “Chiefdom”, and Level 4 is the “Facility”.



To the right of Sierra Leone, there are three vertical dots. Click on this icon to get the below menu, including the option “Show details”.



Click on “Show details” to reveal the below. The 11-character UID (indicated as “Id” in the below screen) for Sierra Leone is highlighted in blue: ImspTQPwCqd.



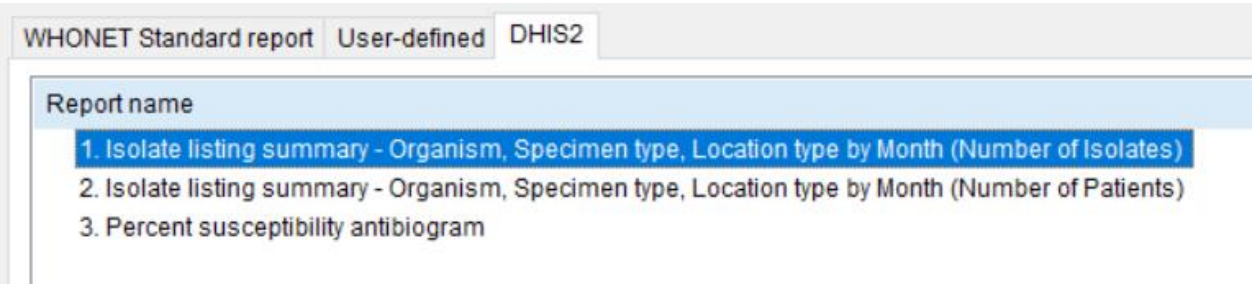
You will need to enter this UID when you export data from WHONET so that DHIS2 will know where to import the data. You will only need to enter this UID once as WHONET will remember it for subsequent data exports.

You do not need to define your individual laboratories within DHIS2. WHONET will do this automatically when it generates the export metadata file. Note – at the present time, WHONET can only manage two hierarchy levels, for example Country and Laboratory. In the future, it should be possible for WHONET to support flexible hierarchies, such as city, state, province, and/or region.

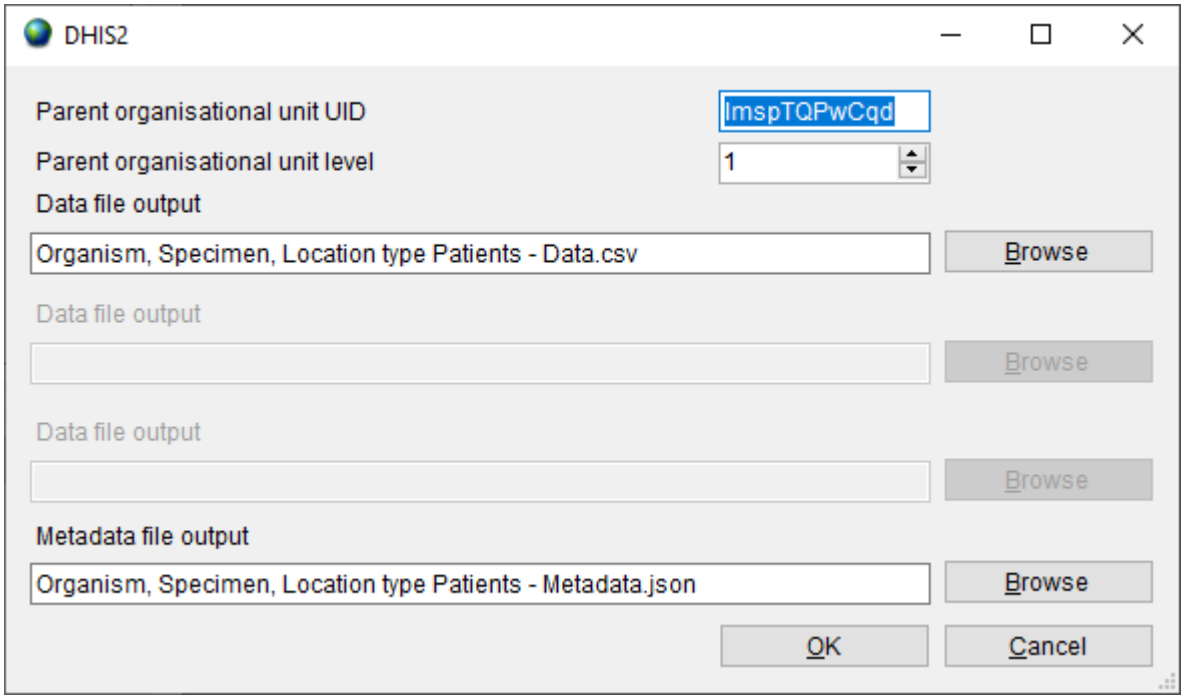
5.2 WHONET-DHIS2 Standard Report

The WHONET-DHIS2 Standard Report can be used to load several years of historical data, and it is also of great value for ongoing monthly reporting of prospective data, including project monitoring and reviewing of emerging trends and threats.

After starting WHONET, choose your laboratory and “Open laboratory”. Then “Data analysis”, “Quick analysis”, and select the DHIS2 tab. Choose the preferred data export option, select your data files, and click on “Begin analysis”.



When you click on “Begin analysis”, you will get the below screen.



In the above screen, initially the “Parent organizational unit UID” was empty, but it has been completed with the UID for Sierra Leone (“Level 1”), as found in an earlier step. “Level 2” will be the laboratory identifier with a unique hashed UID automatically generated by WHONET during the export.

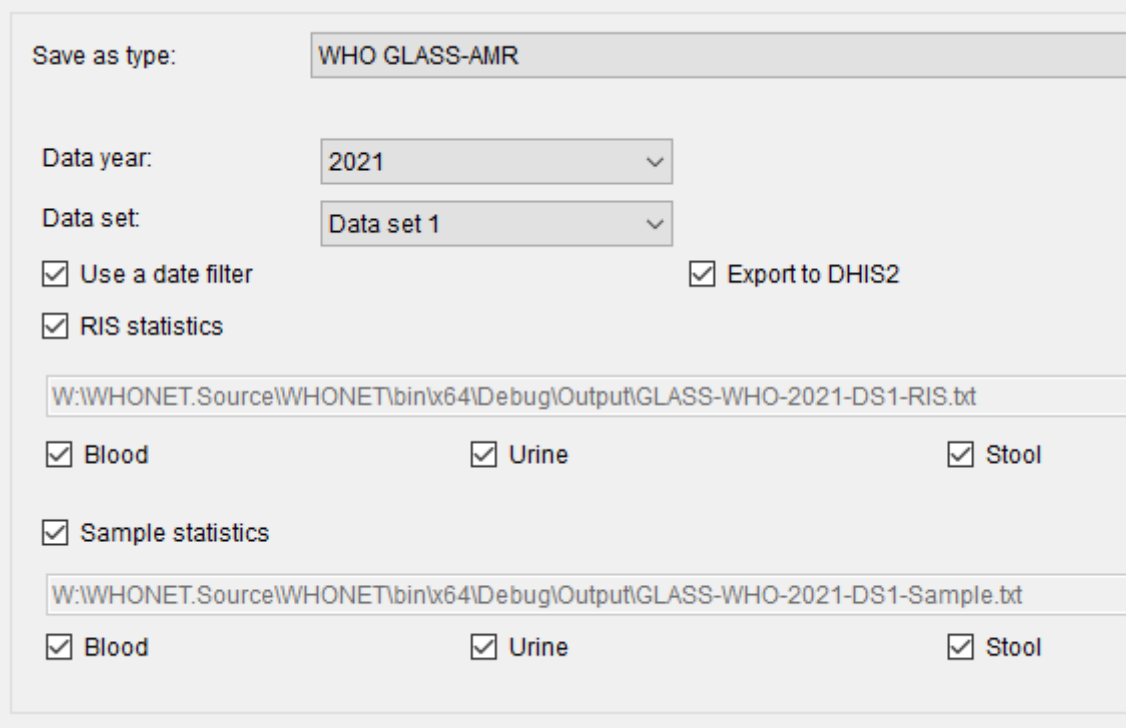
WHONET suggests default names for the “Data file” and the “Metadata file”, but the user may change the default names. These two files can then be uploaded to the DHIS2 platform first the metadata file with the required DHIS2 UID data definitions followed by the data file with the statistical data context.

After reviewing the UID and output file names, click on “OK”, and WHONET will run a series of analysis to generate the output files.

5.3 WHO GLASS export

The WHO Global Antimicrobial Resistance and Use Surveillance (WHO GLASS) project has several possible reporting modules. The initial and core module of WHO GLASS, now described as WHO GLASS-AMR, is designed for the annual monitoring of aggregate national statistics for specific antimicrobial results from eight priority pathogens and four priority specimen types (Blood, Urine, Genital, Stool). Further information about WHO GLASS can be found on the WHO GLASS home page www.who.int/initiatives/glass and in the “WHONET for GLASS Manual” available on the WHONET Documentation page, www.whonet.org/documentation.html..

WHONET has supported this module since 2015 through the WHONET “Combine, export, and encrypt data files” option on the WHONET “Data entry” menu creating two GLASS files: 1) Sample statistics; and 2) Antibiotic “RIS” details. As seen in the below screen.

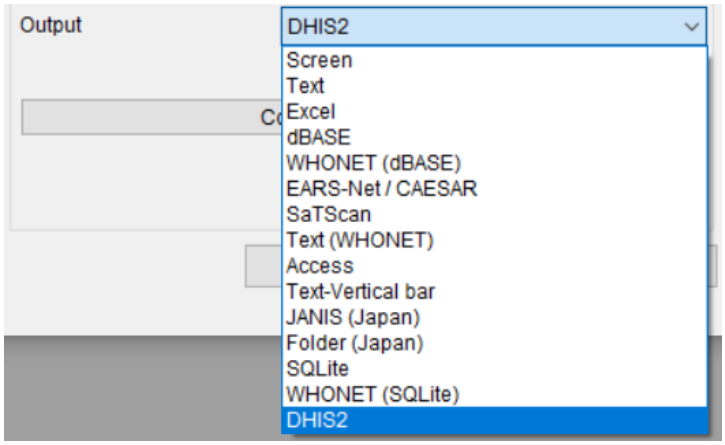


After selecting the data files (typically one year of data from all laboratories in the country) and checking “Export to DHIS2”, the user clicks on “Combine” to proceed to the DHIS2 export screen displayed in the previous section. If this is the first time a DHIS2 export is performed, the user must enter the UID for the “parent” location, typically the country name. For subsequent exports, WHONET will remember the parent UID previously entered.

5.4 Isolate-level export

In addition to the above pre-defined data export options, the user also has the ability to run *ad hoc* user-defined exports for certain WHONET analyses, using WHONET standard features for selecting organisms, isolate filters, and options, such as “All isolates” or “First isolate per patient”. An analysis of particular interest is the WHONET “Isolate listing” analysis, which permits the export to DHIS2 of isolate-level details, as opposed to the aggregate statistics described in Sections 5.2 and 5.3.

The user selects the analysis parameters in the usual way, and for supported analyses, selects “DHIS2” from the list of Output options. The user can then click on “Configure output files” to get the DHIS2 export screen shown earlier to enter the desired names for the DHIS2 export files and the Parent UID if needed.

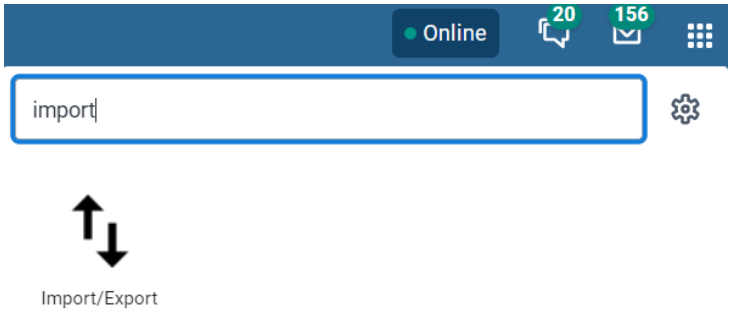


The user then clicks on “Begin analysis” to begin the analysis and data export. If the user has selected “Isolate listing” as the analysis type, then WHONET will export data in the format of DHIS2 “Events”. If an aggregate statistics analysis output has been requested, then WHONET will export data in the format of a DHIS2 aggregate “Data Set”.

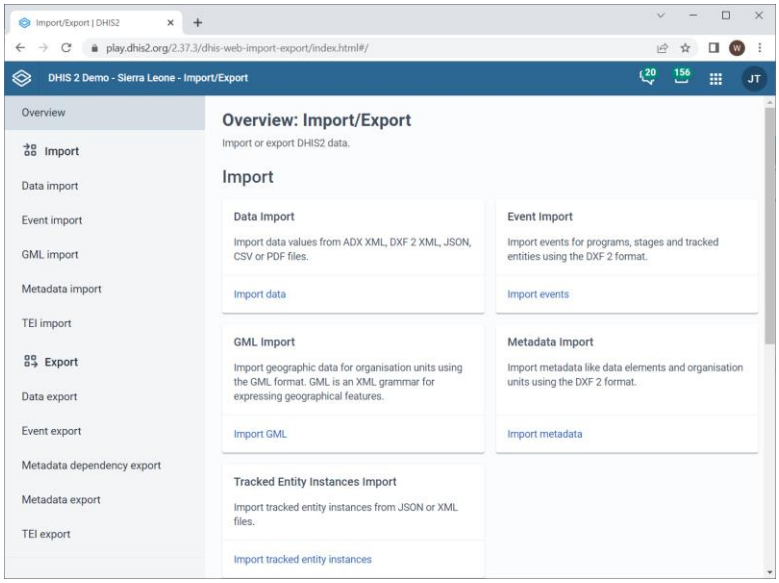
Part 6. Importing data into DHIS2

As described earlier, whenever you export data from WHONET towards DHIS2, WHONET will create two files: 1) the data file (in CSV format) with the content that you desire; and 2) the DHIS2 metadata file (in JSON format) which provides the information needed by DHIS2 to understand and organize the data that are importantly. Consequently, when you import into DHIS2, first you must import the relevant metadata, which you then follow with import of the relevant data.

You can find the DHIS2 “Import/Export” application in the DHIS2 app menu. If you do not immediately see this option, you can search for it by typing “import” or “export”, as below.

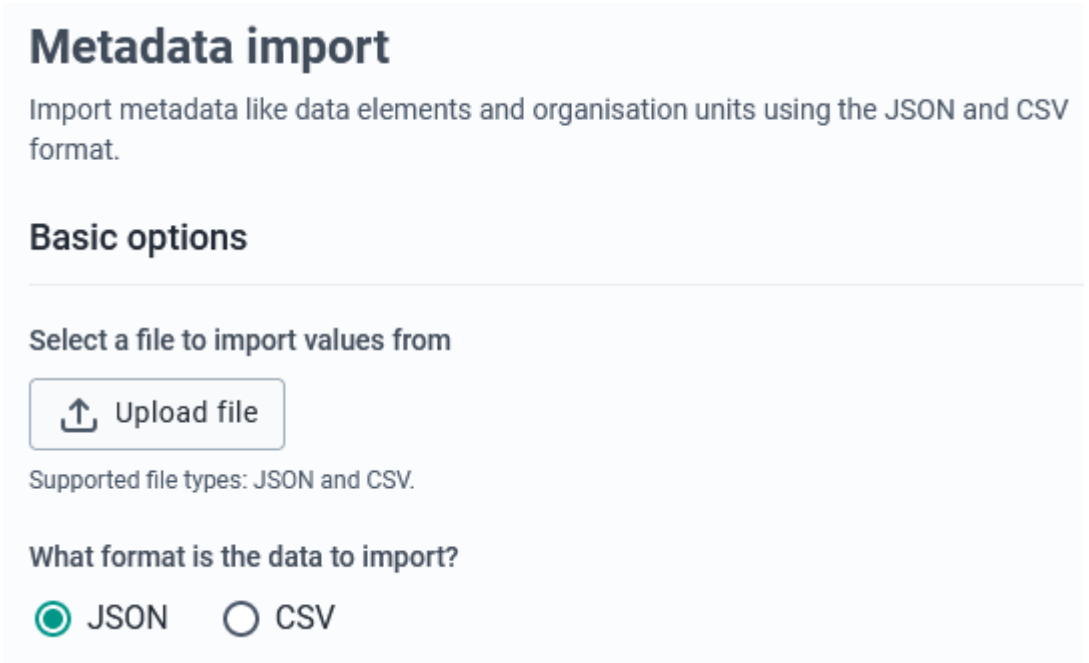


Click on this link to view the import and export features below. There are five options for importing data and five for exporting data. The import options include “Data import” for importing aggregate statistics “Data Sets”, “Event import” for importing isolate-level records, “GML import” for importing GML maps, “Metadata import” for importing metadata, and “TEI import” for importing the Tracked Entity Instances (TEI) used by the DHIS2 Tracker module.



6.1 Importing Metadata (both aggregate statistics and isolate-level details)

From the above menu, the user clicks on “Metadata import” to get the below screen. With “Upload file”, the user selects the desired metadata file that was created by WHONET, which is “Organism, Specimen, Location type isolates – Metadatam.json” in the below example. The user also selects “JSON” as the import format.



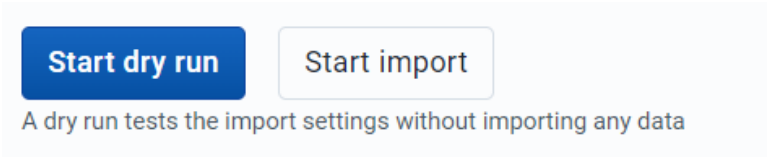
There are several additional “Standard” and “Advanced” options controlling the import, but the default options generally work well for most users.

When the user is ready to import the data, there are two options:

- Start dry run: This option does a “test” import to ensure that the data file formats and content are valid, but no data are actually imported. This is a good option to

verify there are no unexpected errors in the data file. Before there is good confidence and experience with data imports, it is useful to conduct “dry runs” for a quick data check.

- Start import: When the user is ready to perform a real run. In addition to the base validity checks performed during a dry run, a real import may disclose additional issues during the import.



DHIS2 will then indicate “Job started” (at the bottom of the screen) and eventually “Completed” (at the top of the screen) with a summary of the import as below indicated a successful “Dry run”. If there are errors, then the word “Error” will appear in red with a description below of the issues encountered.

Job summary

Organism, Specimen, Location type Isolates - Metadata.xml - 2022-02-20 16:26:13

Completed | Dry run

Summary

Created	Deleted	Ignored	Updated	Total
280	0	0	0	280

Details by type

Type	Created	Deleted	Ignored	Updated	Total
CategoryOption	62	0	0	0	62
OrganisationUnit	1	0	0	0	1
CategoryOptionCombo	210	0	0	0	210
DataElement	2	0	0	0	2
CategoryCombo	1	0	0	0	1

In the above example, DHIS2 has imported 280 “Data Set” items, each of which has a unique UID. There were 62 “Category options” created, such as *Staphylococcus aureus*, *Escherichia coli*, Blood, Urine, Male, Female, Outpatient, Emergency Room, *etc.* There was a single “OrganisationUnit”, which was the WHO Test Hospital in this example, such as “*Escherichia coli* in females in urine in the outpatient setting”.

Following the above success dry run, a real import can be performed with the same feedback summary provided above, but without the comment “Dry run”.

Job summary

Organism, Specimen, Location type Isolates - Metadata.xml - 2022-02-20 16:31:56

Completed

In subsequent metadata imports, DHIS2 will check to see whether any of the data items have been previously defined in the system, and if yes, then these items will not be “Created” again, but rather “Updated”, as in the below with an immediate re-import of the same metadata.

Summary

Created	Deleted	Ignored	Updated	Total
0	0	0	280	280

Details by type

Type	Created	Deleted	Ignored	Updated	Total
CategoryOption	0	0	0	62	62
OrganisationUnit	0	0	0	1	1
CategoryOptionCombo	0	0	0	210	210

The previous example highlighted the import of metadata for a DHIS2 Data Set. The below example follows the same steps, but for a DHIS2 Event import with 68 Data Elements (such as “Patient ID”, “Age”, “Gender”, “Location”, “Specimen date”, “Specimen type”, “Organism”, “Ampicillin result”, Ciprofloxacin result”). There is a singe OrganisationUnit, which was “Updated”, since the laboratory code was defined during an earlier import. There is also a single “Program” for this isolate listing “Event program” and a single “ProgramStage”, which is always the case for “Event” data. In contrast, “Tracker programs” can have multiple program stages.

Job summary

Isolate listing-meta.xml - 2022-02-20 17:03:27

Completed

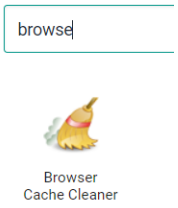
Summary

Created	Deleted	Ignored	Updated	Total
70	0	0	1	71

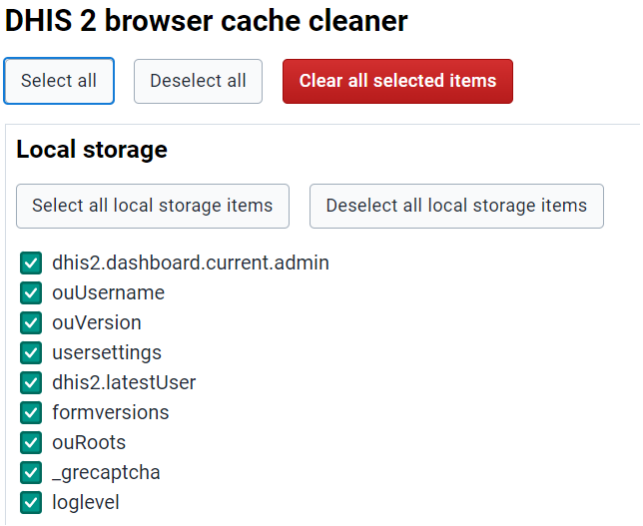
Details by type

Type	Created	Deleted	Ignored	Updated	Total
OrganisationUnit	0	0	0	1	1
Program	1	0	0	0	1
DataElement	68	0	0	0	68
ProgramStage	1	0	0	0	1

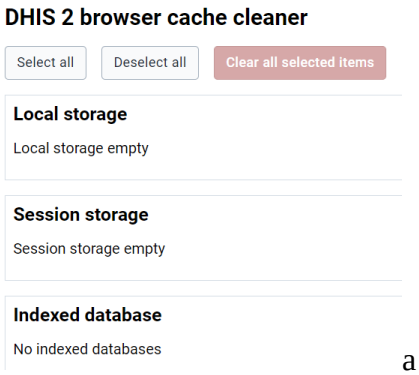
After importing data elements and data sets, sometimes the user needs to clear the DHIS2 “cache” to ensure that DHIS2 is working with up-to-date information. This is accomplished from the “Browser Cache Cleaner” on the DHIS2 App menu, as below.



The user can choose “Select all” and “Clear all selected items” to ensure that the active DHIS2 setting are up-to-date.



In the below, the browser cached has been emptied.



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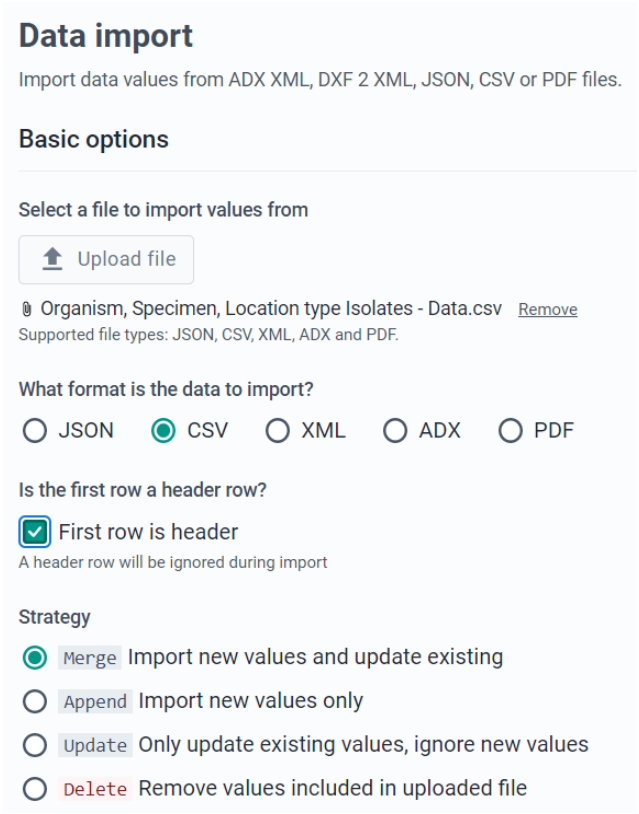
6.2 Importing Data Sets (aggregate statistics)

The steps for importing aggregate Data Sets parallels those described above for important metadata. But rather than “Metadata import”, the user clicks on “Data import” to get the below screen. As behavior, the user chooses “Upload file” to select the desired CSV file. Then the option “CSV” should be selected, as well as “First row is header”. There are several additional optional and advanced options, but the default settings generally work well for most users.



The users then may select a “Dry run” to test the validity of the data file or a true import to import the data. A summary of the successful import is then provided, as below.

Job summary

Organism, Specimen, Location type Isolates - Data.csv - 2022-02-20 16:56:35

Completed

Summary

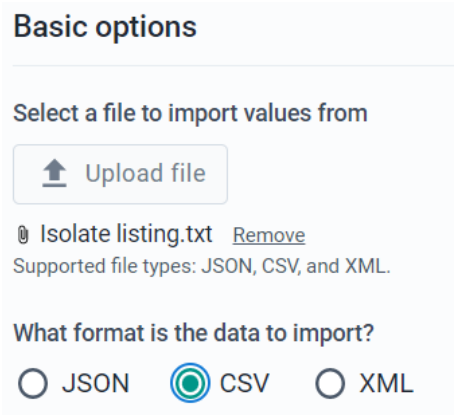
Status	Description
SUCCESS	Import process completed successfully

Created	Deleted	Ignored	Updated	Total
210	0	0	0	210

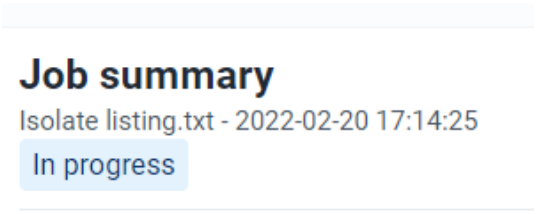
In this example, 210 values were imported corresponding to the various organism, specimen type, location, month, and other combination counts in the original data file. If the same data file is reimported with the default settings, then these values will be “Updated” (replacing the values that have been previously imported) rather than creating them new or adding them to the totals previously entered.

6.3 Importing Events (isolate-level details)

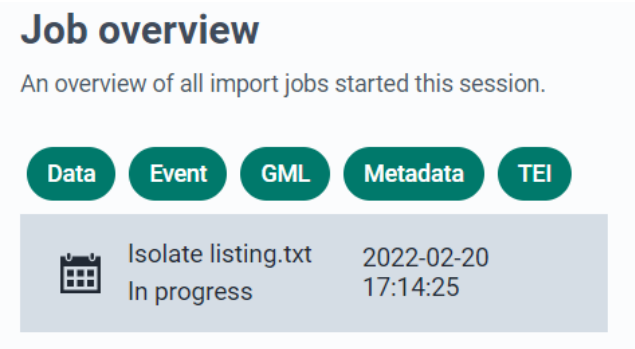
The process of importing isolate-level WHONET records into DHIS2 parallels the steps described above for Data Sets, but the user chooses “Event import” rather than “Data import”. The user interface is shown below.



Importing granulate isolate-level data (for example, individual data elements for 1,000 isolates) is much more time-consuming than importing aggregate statistics (summary counts for the 1,000 isolates), so you will likely see an “In progress” comment as below.



The left-hand menu provides an option for Job overview, which permits a periodic check on the status of import jobs, as well. The process can be very slow, and the job overview below provides no estimate as to how much longer the import may take. For a system administrator with access to the DHIS2 database backend logs, then the status of the import can be monitored more closely to ensure that the import is progressing.



Part 7. Visualizing data within DHIS2

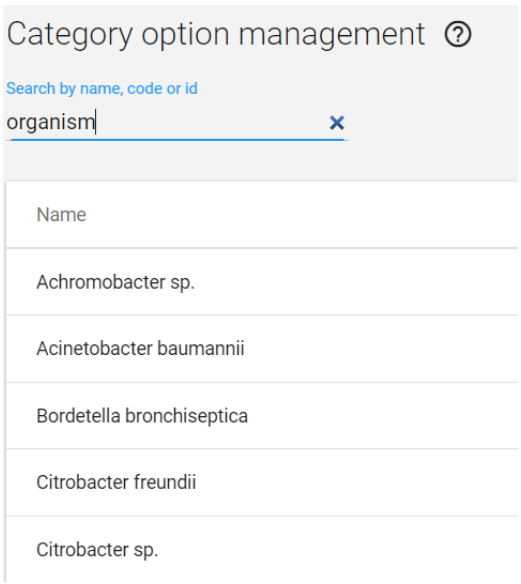
Once the data and metadata have been successfully imported into DHIS2, it is possible to utilized standard DHIS2 functions for reviewing the results.

7.1 Metadata

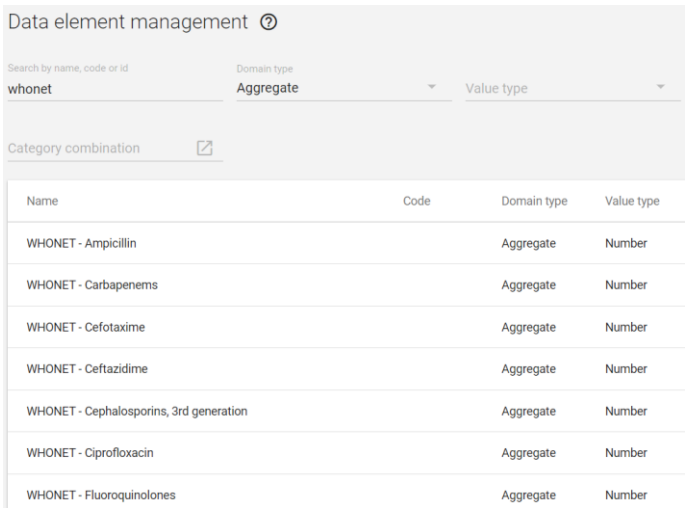
Utilizing the DHIS2 “Maintenance” app, we can visualize the metadata that were exported from WHONET and imported into DHIS2, such as the below examples. The

DHIS2 Demo website will have a mixture of standard definitions provided for Sierra Leone, as well as the new WHONET definitions uploaded in this tutorial. In the below examples, search words have been entered to highlight the items created by WHONET.

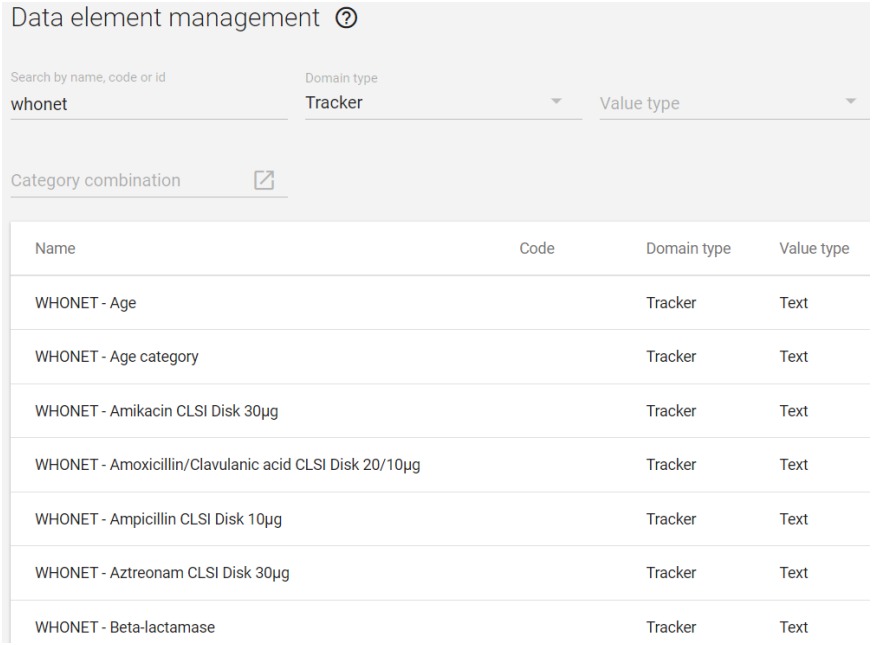
Category options – Organisms. This list automatically matches exactly the organisms found in the user data files.



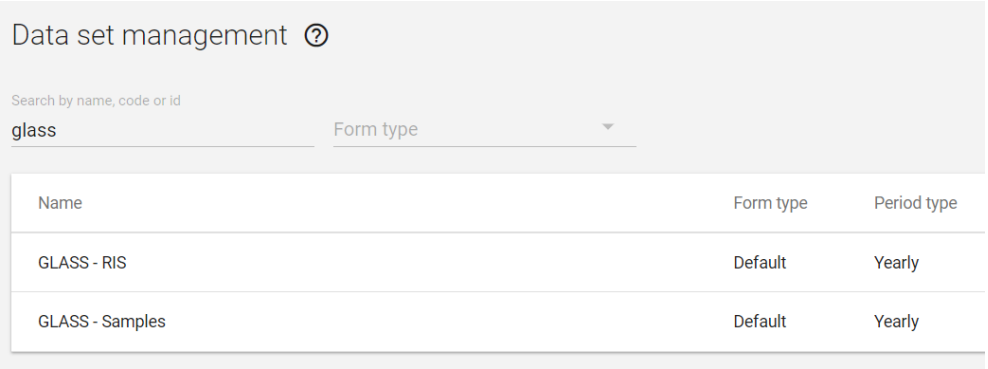
Data elements for “Aggregate” statistics



Data elements for “Event/Tracker” values

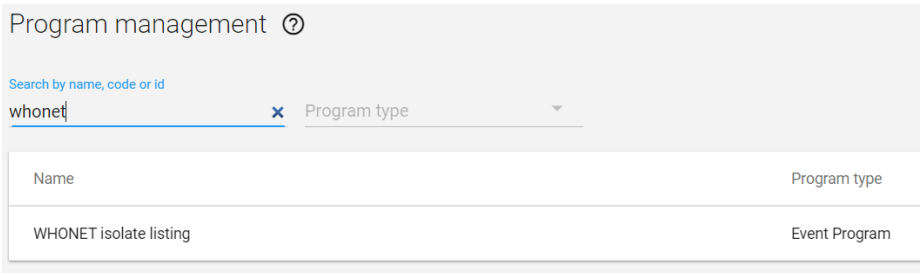


Data Sets – for WHO GLASS



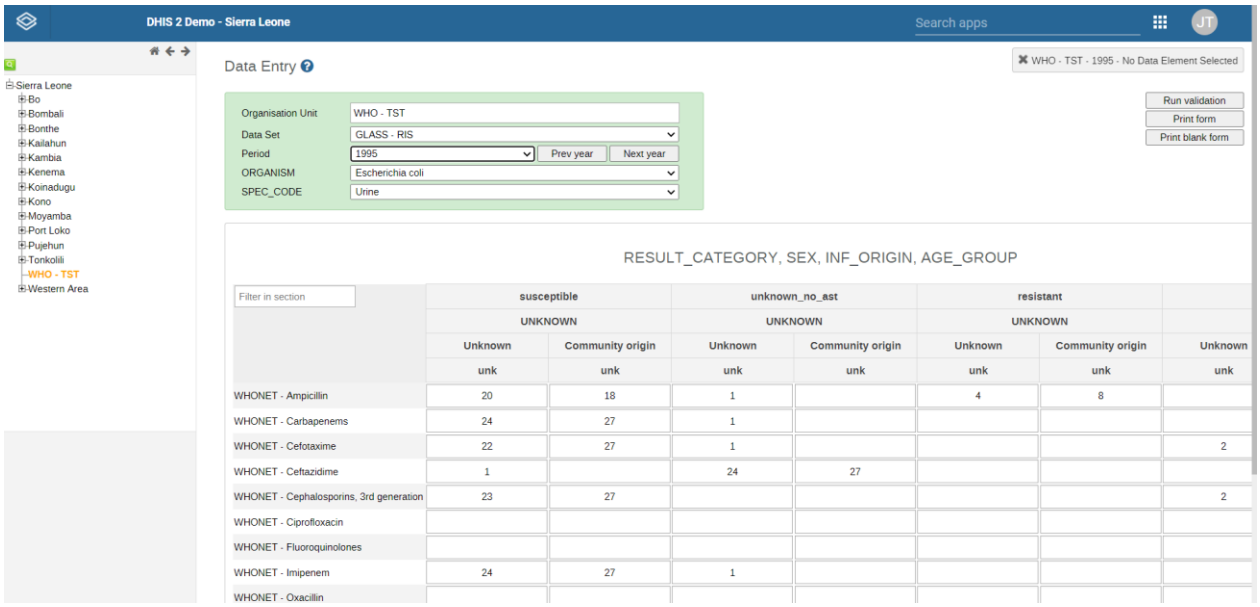
Organisation unit for the WHO Test Hospital within the Sierra Leone DHIS2 Demo database at “Level 2”.

Event program for a WHONET isolate listing

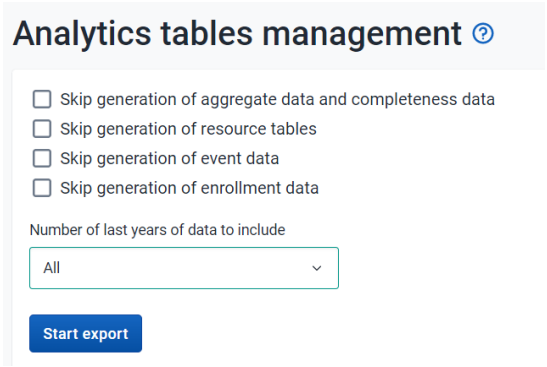


7.2 Data Sets

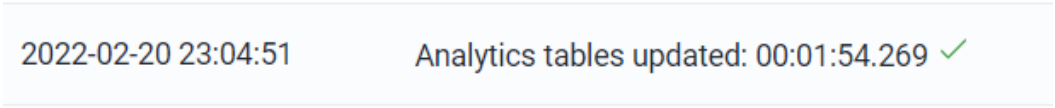
The imported Data Sets can be visualized within the DHIS2 “Data Entry” application available on the DHIS2 app menu. In the below, “WHO – TST” has been selected as the Organisation Unit, the “GLASS-RIS” Data Set has been selected for 1995 (corresponding to the sample data from the WHO Test Hospital) for *Escherichia coli* in Blood. Each row of the table indicates that number of Susceptible, Intermediate, and Resistant results (stratified by WHO GLASS sex, age group, and infection origin categories for each GLASS antibiotic.



Aggregate data stored in DHIS2 Data Sets can be analyzed and displayed through the “Data Visualizer”. However, the Data Visualizer does not work directly on the raw data entered into DHIS2. Rather they run off of optimized “Analytics Tables” to ensure best performance. In the default DHIS2 configuration, Analytics Tables are typically updated automatically every night to avoid interference with performance during daytime operations. But one can also choose to update the DHIS2 Analytics Tables on demand by selecting “Data Administration” from the DHIS2 App menu and then “Analytics Tables” to get the below, and “Start export”.

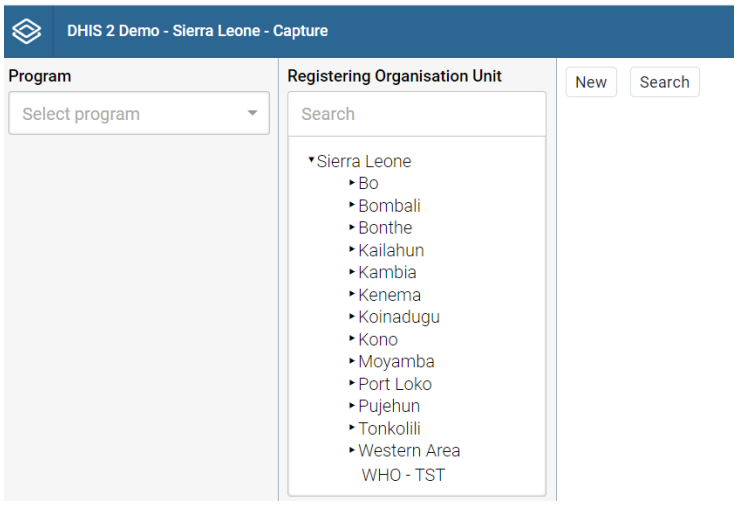


The user will see a progress log indicating the current step with the final step below indicated “Analytics tables updated”. If the focus is on aggregate statistics, one may choose to select “Skip generation of event data” and “Skip generation of enrollment data”, which can significantly slow down the updates of the Analytics Tables.



7.3 Events

Results from the “Events” imported can be visualized from either the older “Tracker Capture” DHIS2 app or the newer “Capture” app by selecting the laboratory (WHO – TST in the example and the desired program (WHONET isolate listing) as in the below.



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Part 8. Limitations of DHIS2 for antimicrobial resistance data management

DHIS2 core applications do have significant limitations with regards to the management of antimicrobial susceptibility test data.

- Correct counting of patients. This is a problem for all data models.
    - Data Sets: For monthly aggregate statistics, a patient may have *E. coli* in January and in February and a *S. aureus* in June. For the annual aggregate totals, this patient will be counted three times.
    - Event Programs: DHIS2 does not use any patient identifiers when it counts results, leading to overcounting of any patients with multiple results.
    - Tracker Programs: The use of unique patient identifiers improves ability to count patients over tracker programs. However, if a patient has multiple isolations of a single species or multiple species, the data analyst has limited ability over which isolate DHIS2 will analyze, typically the final isolation of the final organism, and ignoring all other results. A challenge with the tracker model is that it has rich features for tracking "patients" at a high-level. But patients often have multiple samples, each of which may have multiple isolates, each of which may have multiple (and unpredictable depending on the organism) antibiotics. This multilevel relational complexity is not captured within DHIS2 core functionality.

- Management of antimicrobial susceptibility test results. Both Event and Tracker Programs allow the storage of isolate-level antimicrobial susceptibility test results. But the appropriate management of antimicrobial test results and their interpretation is complex.
    - Different antibiotic panels depending on organism groupings, such as Enterobacterales or *Streptococcus* species other than *Streptococcus pneumoniae*.
    - Interpretation of disk diffusion zone diameters (such as 16mm) or MIC and Etest MIC values (such as MIC >256) by recognized CLSI or EUCAST criteria for particular species or species groupings. And these interpretative criteria are updated and expanded annual. If a laboratory enters only "R", "I", "S" category results, then data management is simpler, but also less rich and new interpretative criteria cannot be applied retrospectively.

  These are significant limitations of the DHIS2 data model and core functionality, but there are potential solutions and new DHIS2 directions. As mentioned in an earlier section, it is possible for "DHIS2 Developers" to create new applications and functionality outside of DHIS2 core features.