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Exploring the Need for Research Data Management Services: A Study of CSIR Laboratories in India

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ABSTRACT

The realisation of Findable, Accessible, Interoperable, and Reusable (FAIR) research data principles is contingent upon proper Research Data Management (RDM) practices by the researchers who generate data. Accordingly, it is pertinent to investigate how they manage their research data and gain insight into researchers' need for RDM support service. This study explores the nature of research data generated by researchers, their perception of RDM and their needs for library services. An online survey comprising 48 questions was administered to researchers at the Council of Scientific & Industrial Research (CSIR) laboratories, yielding 173 complete responses. The survey findings indicate that there are significant gaps in RDM awareness and practice: 97 % has limited knowledge of RDM, the majority are not aware of FAIR data principles (74 %) and 71 % lack knowledge of metadata. The results also reveal differences in research data across domains, indicating the need for tailored data management approaches. Despite the knowledge gaps, there is high level of willingness among researchers to share research data (86 %), keenness to receive training on research data management (98 %), and interest in availing research data services if offered by the library. This study concludes that researchers currently lack the necessary knowledge and skills for effective data management and there is a need for libraries to take a forefront role as facilitators of research data management services.

Keywords: Scientific and technical research; Research data management; Data sharing; Research data service; Library

1. INTRODUCTION

The recent development of Research Data Management (RDM) in the Open Science landscape requires researchers to manage their research data in order to enable Findable, Accessible, Interoperable, and Reusable (FAIR) research data[1]. More so in terms of the research data that are publicly funded. The rationale behind this is the value that data holds, which can be re-visited to consider different perspective from the initial findings, verify data, besides others. This ushers in the need to assess researchers' understanding of the research data they generate and its management. Based on this, appropriate Research Data Services (RDS) can be provided in libraries to support researchers as advanced Research Support Services (RSS), helping manage their research data from planning to the publication of datasets and reuse of research data, which continues beyond the lifecycle of any research project[2]. This study surveyed researchers from the Council of Scientific & Industrial Research (CSIR), which is an autonomous body of the Department of Scientific & Industrial Research (DSIR) under the Ministry of Science and Technology, Government of India (GoI). CSIR has 38 national laboratories across India in various Science and Technology (S&T) domains, conducting multimillion research projects and generating vast amounts of varied data, the management of which is essential to extract the value from this data. The CSIR laboratories are categorised into five domain clusters: biological sciences, chemical sciences, engineering sciences, information sciences, and physical sciences. Understanding the value of research data generated from publicly funded research in the field of S&T in India and the significance of RDM for the FAIRification of research data by researchers in CSIR laboratories cannot be overemphasised. The social implication of this study is to bring to light the transparency of the publicly funded research through FAIR data practice. This research conducted an online survey to understand the research data generated by the researchers, storage of data, the data sharing practice, awareness of RDM, and the need for library services to support the scientific community. The practical relevance of the study is the identification of the gap in RDM practice which will guide the development of RDS, inform policy making and thereby enhance conformity to global compliance.

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2. LITERATURE REVIEW

Literature study indicates that surveys on researchers are being conducted to understand their data management practices and their perception of RDM, in order to assess the best practices for RDM as a scientific process, the need for RDS from library, and the extent to which libraries support the scientific community[3-5]. Domain-specific researcher surveys are also conducted, putting into perspective the need for discipline-specific data and its proper management for reproducibility and reuse. Several studies on the survey of researchers in the field of S&T have been reviewed, based on which this study has been found necessary and built on. A study on five science disciplines indicated that metadata control and data management training remain problem areas, and researchers desire dynamic features from repositories rather than just long term storage[6]. Herres-Pawlis[7], *et al.* studied the major sub disciplines of chemistry in the NFDI4 Chem project to assess chemistry researchers' research data management and continuous analytical assessments according to the project goals for the national research data infrastructure initiative in Germany. In alignment with the same goal, a study was conducted on the NFDI4BIOIMAGE community by Schmidt[8], *et al.* the results found community acknowledgment of the value of RDM and data sharing. However, there are hurdles in the implementation of FAIR data practices, highlighting the need for information, guidance, and standardisation. Sharing data and requesting data directly from researchers are common practice among the medical faculty, but less use is made of repositories as per the study conducted by Fichtner[9], *et al.* Neuroscience researchers perceive barriers in their RDM and data sharing, but they are willing to share their data and recognise the need to enhance their RDM skill[10].

A study on civil and environmental engineering researchers was conducted by Chen[11], *et al.* to understand their research practices and recommend supporting strategies to be provided by libraries and other units involved in the research ecosystem. Meanwhile, in the technology field, researchers showed great interest in RDM but lacked in-depth knowledge and practice of RDM and FAIR data practices[12]. In the field of biological sciences, Koopman and de Jager[13] conducted a study on researchers' data management and archiving initiatives, concluding that there is a fear of valuable data loss and a lack of policy, strategy, and support. The survey of researchers in medical and related fields revealed that data sharing was not widespread, and there is a need to raise awareness about safe data preparation for sharing, which data librarians should train researchers on[14]. A survey of clinical researchers concluded that there is a need to train physicians with a specific focus on data statistics, cohort and biobank construction, and data management[15]. In the same domain a survey was conducted by Kersloot[16], *et al.* to gain insight into not only research data management but particularly clinical researchers' understanding and experience of data FAIRification, which indicates that there is a need for training, support, and tools. Stojanovski and Vrana[17] researched the Croatian scientific community and found that researchers are partially engaged in open science.

In the Indian scenario, some studies on RDM in libraries have been conducted, indicating the early stages of RDM[18-22] while Bhardwaj[23] discussed the prospects of research data repositories in India. Limited research has been conducted on surveys of researchers[24-25] with none specifically focusing on S&T domain researchers, according to the literature. This study intends to address this research gap and understand RDM as part of scientific practice within the scientific community, in order to assess their need for RDS from the library.

3. OBJECTIVES OF THE STUDY

In view of the above, the specific objectives of the present study are:

- To investigate the nature of science and technology data so as to ascertain what type of data is generated, domain-specific data, the variation among the different disciplines of S&T, file formats, storage medium, and data sharing
- To investigate the extent to which RDM has been adopted as part of the research process and
- To study the need for RDS from CSIR Libraries by the scientific community

4. METHODOLOGY

An exploratory study was conducted using an online survey as the data collection method. The research process workflow is outlined in Fig. 1 with further elaboration.

Step 1: It involves searching and identification of the relevant literatures and datasets comprising questionnaires in the literature database and subsequently trailing to data repository. Scopus database was searched with "Research Data Management" AND ("Researchers" or "Scientist" or "Academic") AND "Libraries". Literature was thoroughly reviewed to analyse questionnaires on researchers.

Step 2: This phase involves selection of appropriate questions from the retrieved questionnaires, re-framing questions as per requirements and also creating new questions as deemed necessary. The questionnaire for the survey was designed by adapting the Generic survey Canadian Research Data Management Survey Consortium published as a dataset in the Borealis data repository under CC-BY 4.0 license[26] and incorporating inputs from various literature studied on researcher surveys. The questionnaire was designed using Google Forms tool for the online survey. The questionnaire consists of 48 questions, with 13 open ended and 35 closed ended questions.

Step 3: This phase adopted the web content analysis method for studying the researchers community and extracting data from the website. The official website of the CSIR laboratories was searched to find email address of the researchers. An earlier survey of CSIR libraries resulted

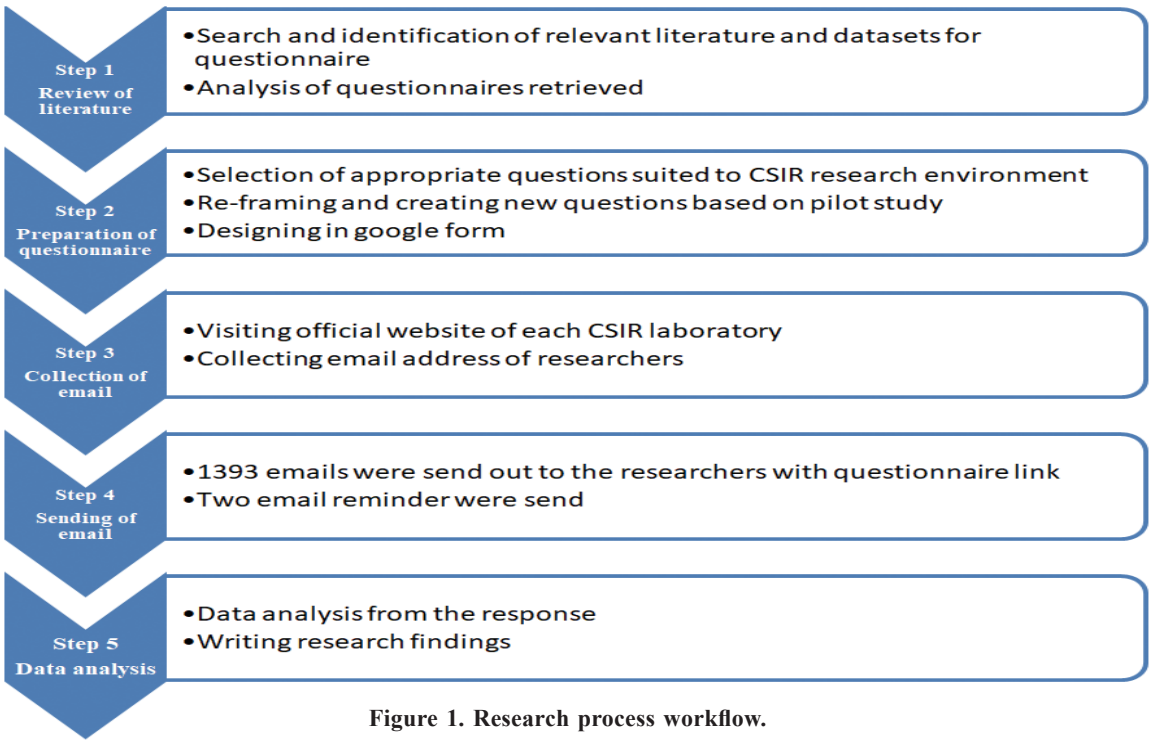

Figure 1. Research process workflow.

in 20 libraries participating in the online survey out of a total of 38 laboratories[27]. This study is the second phase of research on RDM in CSIR laboratories and the role of libraries in supporting researchers through the provision of RDS. Email was used as the communication medium to reach the scientific community in the 19 participating CSIR laboratories. The email addresses were collected from the websites of the CSIR laboratories, wherein one laboratory website did not provide the email address of the scientific community resulting in a survey of researchers from 19 CSIR laboratories A total of 1393 email addresses of CSIR researchers were collected from the official websites

Step 4: Online questionnaire was employed for data collection. Email was send to email address of 1393 researchers with the link to the questionnaire. The survey was administered online using Google Forms tool. Correspondence with the researchers began in mid-September 2023 and remained open till January 31, 2024, with two reminder emails. As no further responses were received after mid-January, the survey was closed at the end of January.

Step 5: Data analysis and writing the research findings. The charts generated by Google Forms were used for data representation and Libra Office Calc used for data in tabular form and visualised in chart form.

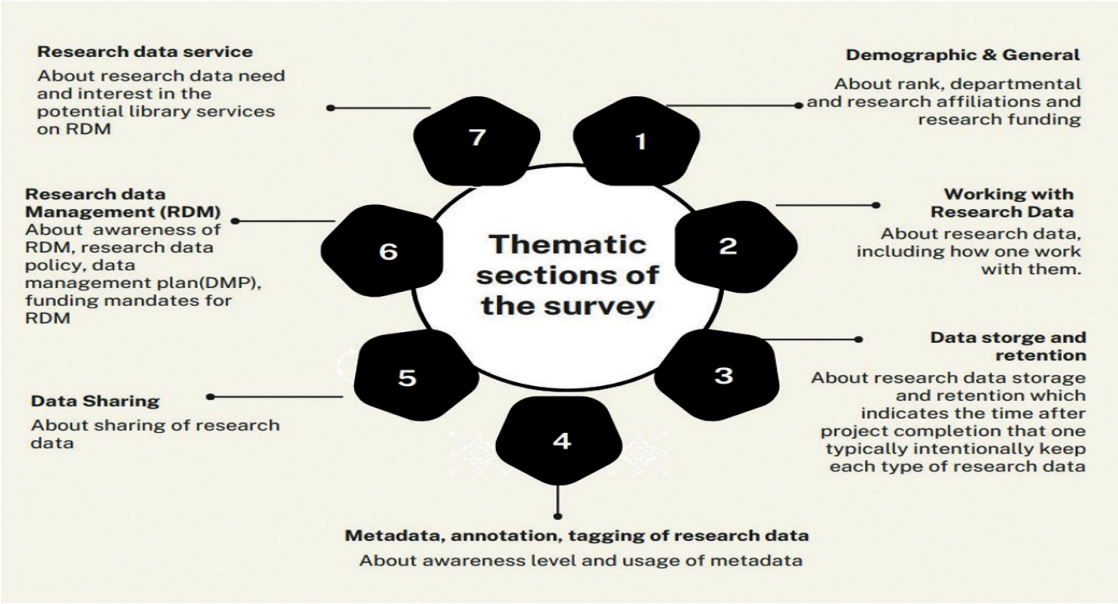

Figure 2. Thematic sections of the survey.

5. FINDINGS

The survey questionnaire was categorized into seven thematic sections, as described in Fig. 2. The findings are presented section by section, according to the thematic sections.

5.1 Demographic & General Questions

The scientific community in CSIR laboratories is designated by ranks of scientists, research scholars, and ranks of technical officers. The higher ranks of scientists were more participative in the survey than the research scholars and technical officers, as indicated in Table 1.

Table 2 shows the breakdown of respondents by CSIR domain cluster who participated in the online survey. It indicates that researchers from the Chemical and Engineering Sciences cluster labs were more participative.

The survey also found that 44 out of 173 researchers have cross-discipline affiliations outside their respective laboratories, which indicates collaborative research practice among the researchers.

5.2 Working with Research Data

With the majority of the researchers working on more than five research projects, the data generated by each researcher range between 1 GB to 10 GB per research project as an average, as indicated in Table 3. The amount of data generated by CSIR researchers is huge and growing annually. It is, therefore, pertinent to manage research data for long-term preservation, access over time, and re-usability to derive value from publicly funded research.

Table 1. Rank wise respondents of the scientific community

Rank at CSIR	No. of responses	Percentage
Chief scientist	20	12%
Senior principal scientist	28	16%
Principal scientist	47	27%
Senior scientist	26	15%
Scientist	35	20%
Research scholar	4	2%
Principal technical officer	3	2%
Senior technical officer	2	1%
Technical officer	7	4%
Other: outstanding scientist	1	1%

Table 3. Number of research projects in 5 years vis-a-vis data generated per project

No. of research projects in last five years	>5 research projects	3-5 research projects	1-2 research projects
Responses	74	64	35
Data generated	Responses	Responses	Responses
< 1GB	7	18	15
1GB to < 10GB	41	9	33
10GB to < 50GB	10	0	8
50GB to < 500GB	12	0	4
500GB to < 1000GB	0	2	2
1TB to < 4TB	4	4	2
4TB to 500TB	0	2	0
>500TB	0	0	0

The researchers basically generate digital data, with textual data being the most commonly generated type, followed by multimedia and numerical data, as indicated in Table 4. In a study by Bhardwaj[23] on Indian data repositories in Re3data, the top three content types were found to be scientific and statistical data format, standard office documents and structured graphics, regardless of the discipline. The current study also found instrument-specific and discipline-specific research data generated in CSIR (For instance: CFD, scaleup softwares, Origin, netCDF, IRMS, MC-ICPMS, ICPMS). Therefore, there is a need to understand data at a granular level in order to manage it effectively. Regarding the storage of research data, the preferred

Table 2. Domain cluster wise ranks of the respondents

	CSIR domain cluster					
Ranks	**Biological sciences**	**Chemical sciences**	**Engineering sciences**	**Physical sciences**	**Information sciences**	**Multi-disciplinary**
Chief Scientist	7	2	8	3	0	0
Senior Principal Scientist	2	14	10	2	0	0
Principal Scientist	15	7	18	5	0	2
Senior Scientist	7	7	2	10	0	0
Scientist	6	12	11	6	0	0
Principal Technical Officer	0	0	1	2	0	0
Senior Technical Officer	0	2	0	0	0	0
Technical Officer	0	6	1	0	0	0
Research Scholar	0	3	1	0	0	0
Others	0	1	0	0	0	0
Total	**37**	**54**	**52**	**28**	**0**	**2**

storage methods are the hard drive of the computer/ laptop (91.9 %), external hard drive (83.2 %), and flash drive/USB (56.1 %). These storage devices do not support long-term preservation and access over time, which eventually risks the research data to remain as dark data or being lost perpetually[28]. Only a small proportion of research data is stored in data repositories (12.7 %) which are mostly in institutional repository hosted by the laboratory or the CSIR central. Storage in a repository has a higher chance of long-term preservation, accessibility over time, and even the possibility of data manipulation, specifically open data repositories provides equitable access[29].

Table 4. Types of digital research data generated

Digital content data type	Responses	%
Text (e.g. TXT, DOC, PDF, RTF, HTML, XML)	161	93%
Multimedia (e.g. JPEG, TIFF, MPEG, MP3, Quicktime, Bitmap, Audio/Visual records)	136	79%
Numerical (e.g. CSV, MAT, XLS, SPSS)	111	64%
Geospatial (e.g. raster, vector, grid, boundary files)	20	12%
Models (e.g. 3D, statistical, similitude, macroeconomic, causal)	41	24%
Software (e.g. Java, C, Perl, Python, Ruby, PHP, R)	35	20%
Instrument specific (e.g. fMRI, LSM, Olympus Confocal Microscope Data Format, FLIR Infrared Camera (SEQ)	59	34%
Discipline specific (e.g. BAM, FASTQ, CEL, IDAT, FASTA, PBD, BRK, DICOM, CIF, FITS, DICOM)	39	23%
Other: CFD and scaleup softwares, Origin, netCDF, IRMS, MC-ICPMS, ICPMS	5	3%

Upon analysis, it is found that domain-specific data, instrument-specific and particular file formats are used by researchers, indicating variation among the domain clusters. A word cloud was generated cluster-wise using web-based free word cloud generator (https://wordart.com/), as shown in Fig. 3. It is significant to understand the domain specific data and variation in the management of data.

The responsibility for the storage of research data is found to lie with the researcher/supervisor (91.3 %), who does not always retain research data for the long term, as indicated in Fig. 4.

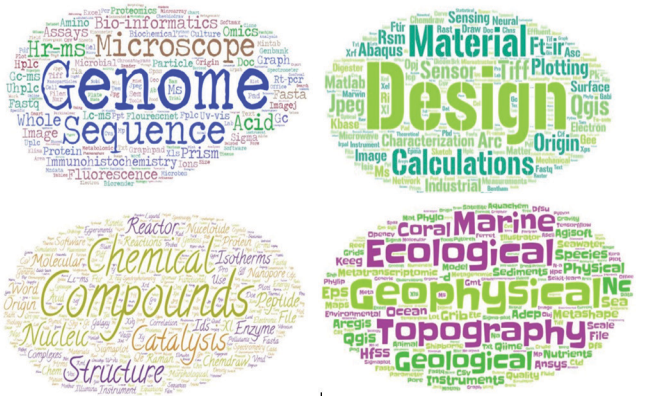

Figure 3: Wordcloud domain specific data generated, instrument specific and file format.

Although there is a higher trend of retention till the data is inaccessible or lost, it is not a sufficient effort, as data retention at an individual level might lack proper data storage and preservation skills, eventually leading to data loss. Data storage and preservation for long-term accessibility are best suited to the library and IT unit, which have the appropriate infrastructure in place as well as skilled staff. The selection of appropriate data repository software is necessary to ensure FAIRification of datasets for hosting in-house, and the identification of an appropriate repository to deposit datasets where in-house infrastructure is not feasible[30].

5.3 Metadata, Annotation, Tagging of Research Data

It is found that the majority of researchers maintain sufficient documentation or descriptions for another person outside the research team to understand or use the research data and retain it in the same file, folder or document to replicate the methodologies that produced the data. However, there is uncertainty among researchers regarding such matters, while some do not practice it. Confusion regarding metadata is evident from the data collected, as most of them have stated their knowledge and usage (40 %), whereas, in the use of metadata fields 46.2 % stated they do not assign metadata. Among the researchers who assign metadata, the preference in the importance of the metadata elements are the title of the dataset (45.1 %), description of the dataset (41.6 %), date of collection (39.3 %), collection method (39.3 %), name of the creator (36.4 %), equipment used to collect data (36.4 %) and other elements fall below 30 % of the preference. The assigning of metadata is encouraging as it is essential for data discoverability.

5.4 Data Sharing

The data sharing in the repository is nominal with 24.9 % within the institutional repository and 23.7 % outside of it. However, there is a higher trend of sharing research data upon personal request (46.8 %). A common

tendency exists for sharing data with immediate collaborators, researchers in the same department, researchers in the same field and from any CSIR laboratory as indicated in Fig. 5. However, there is less preference for share with researchers outside their respective domain or with the general public, with few researchers stating that they do not wish to share their data. The common reasons for researchers not share their research data are that they want to publish their data before sharing it (69.4 %). Some researchers (11.6 %) are not willing to share their research data even if there are no restrictions and embargo, while others do not see the benefits of sharing (10.4 %) and few are unaware that they can share their research data (4 %). Based on these opinions, it is felt that there is a need to raise awareness about data sharing within the scientific community.

5.5 Research Data Management (RDM)

Only a few researchers 3 % are well-versed in RDM, 47 % have basic knowledge of RDM, and the majority 49 % lack awareness of RDM. Awareness of RDM is required in CSIR, and libraries have a significant role in educating researchers about RDM. Researchers' responses regarding funders' mandate on RDM indicate that there is limited awareness of such mandates as 80 % are unaware of them. Regarding FAIR data, although a small proportion of researchers are well-versed (2 %), compliance is non existent, while only 24 % have basic knowledge and 74 % are unaware. There is a lack of knowledge about institutional data policies and Data Management Plans (DMP), as researchers from the same CSIR lab have affirmed and negated, while some stated that they are unaware. DMP typically address questions about research

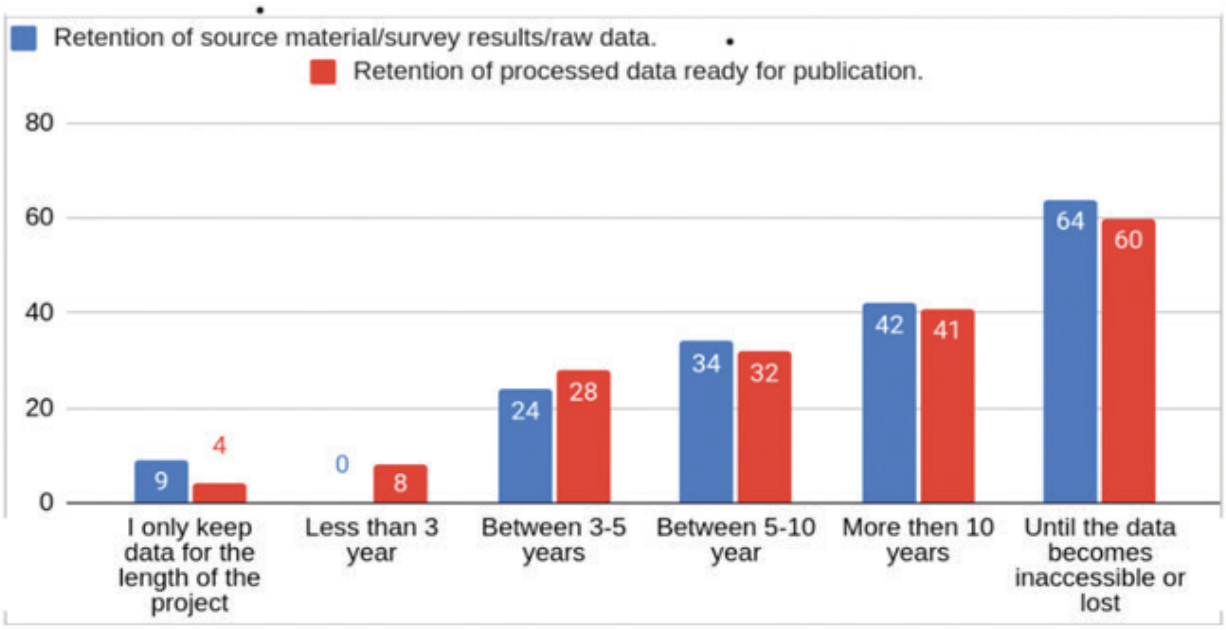

Figure 4. Retention of data.

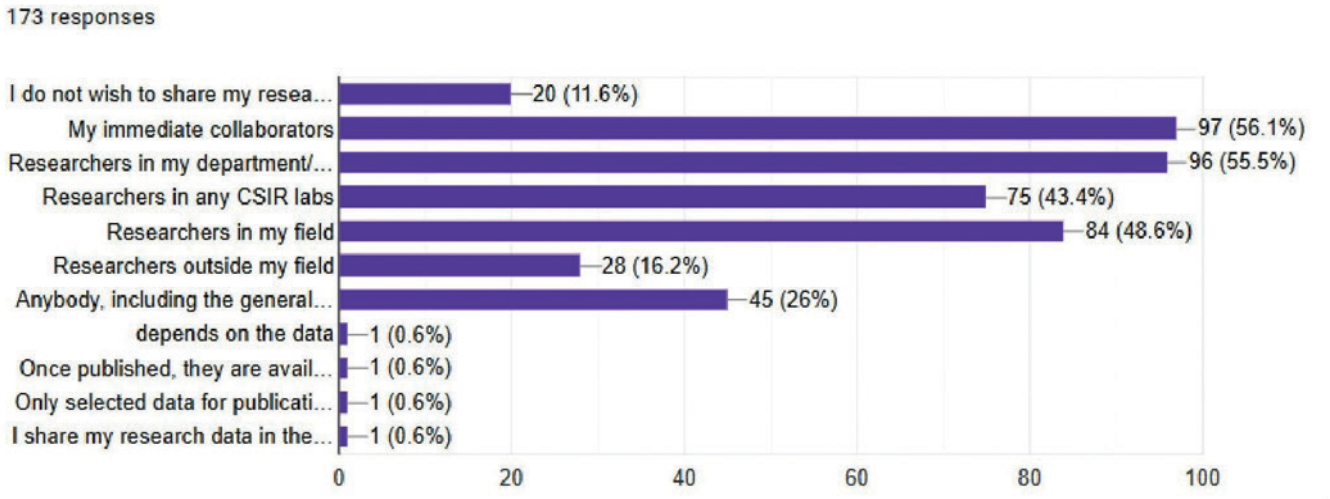

Figure 5. Sharing of research data preference (n=173).

data types and formats: standards to be used for describing data; ethics and legal compliance; plans for preservation, access, sharing, and reuse; responsibilities assigned, and resources needed. The majority (53 %) opined that if they are to draft a DMP as part of a grant application, they would need assistance and/or guided documentation to appropriately address some or all of the sections.

5.6 Research Data Service

Researchers (54 %) need raw data independent of a published research article from other researchers, and they seek it from the researcher who created the data (34 %), the library (18 %), open access data repositories (18 %), datasets from journal publications that publish articles along with raw data (12 %), and a few retrieve data from data journals (9 %). There is no usage of Re3Data, a global registry of data repositories, while there is an indication of the usage of data search engines among researchers (24 %), such as Google Dataset search, espacenet, Elsevier data search, Google Dataset, Scifinder, Scite.ai, Github. The library's services are greatly required by the scientific community, as 90 % of researchers stated that it would be helpful if the library provided services for finding data. Researchers have stated that they are often confronted with issues and challenges in generating,

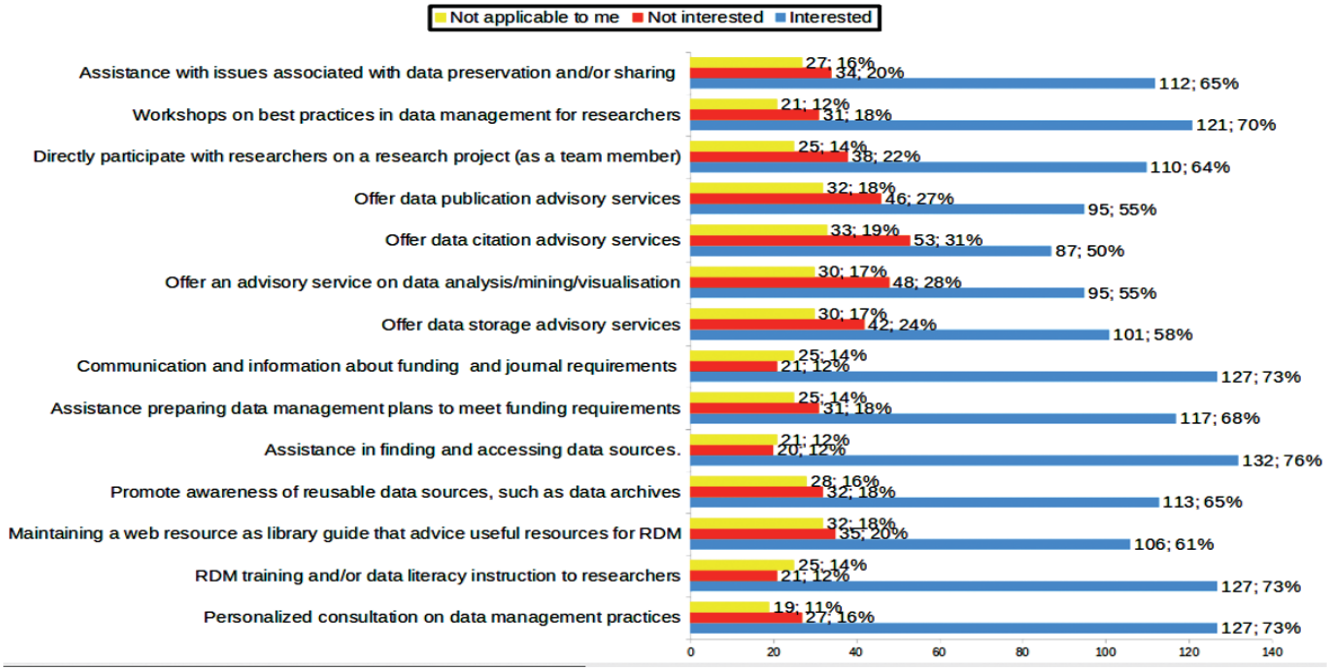

Figure 6. Interest in advisory and support research data services.

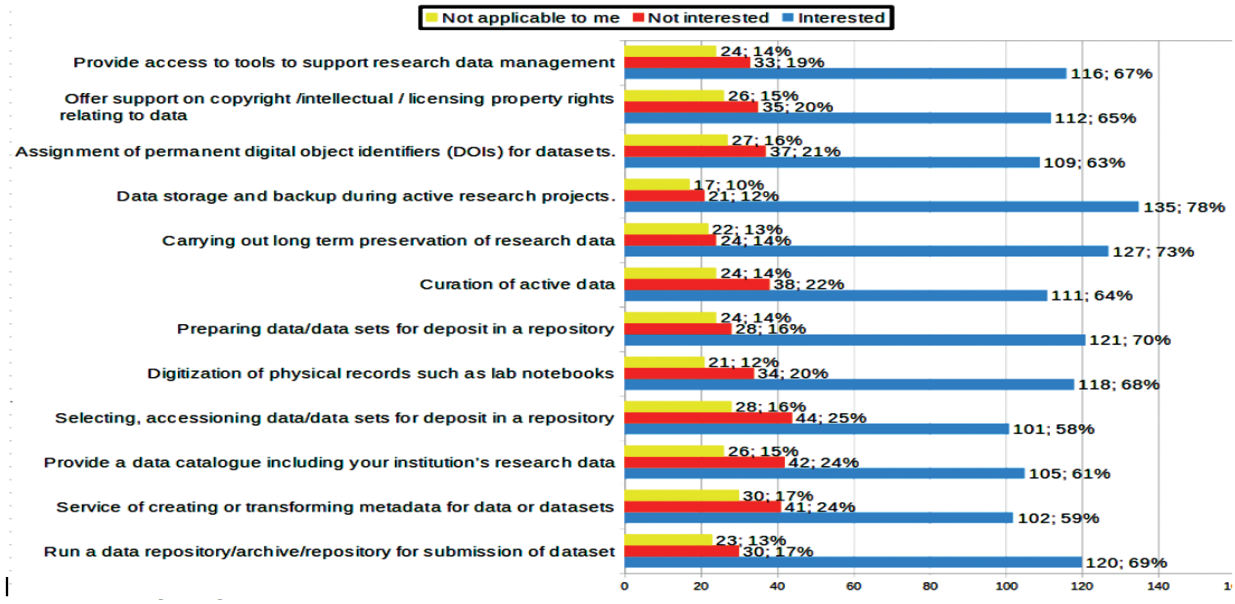

Figure 7 Interest in technical research data services.

managing, and publishing research data. They are interested in availing RDM training, and the library can serve as a space, facility and agent to educate, train and skill researchers in RDM. Researchers have indicated their interest in libraries providing Advisory and Support Research Data Services, as shown in Fig. 6. Researchers' interest in the Technical Research Data *Services* that the library can offer is indicated in Fig. 7. In the first phase of CSIR survey on RDM that covered CSIR libraries, regarding Technical RDS, some library managers considered it primarily the responsibility of another unit, while most gave it low priority. In the current survey, the researchers have indicated that they are interested in Technical RDS if the library can provide it. CSIR libraries should rise to the occasion and facilitate such a service.

6. DISCUSSION

This study finds that researchers have limited knowledge and practice of RDM. The research data generated are at risk of loss, as the data are mostly retained by the researchers, stored on external storage devices or in personal computers, and there is limited data sharing in data repositories for long-term preservation. The common data sharing practice is sharing by individual request, but researchers are willing to share if no restrictions or embargoes are imposed, which is a positive indication. Therefore, libraries should facilitate adequate services. The data loss implication on science and society is tremendously detrimental, as the reuse of data impacts the value of new findings as well as financial resources. There are differences in research data across various domains, indicating a need for domain data-specific management. There is a clear keenness to know more about research data management, which librarians can support through education and liaising with researchers to provide need-based knowledge and skills. Overall the study found that researchers are interested in research data services from the library. Therefore, the CSIR libraries should seize the opportunity to up skill, upgrade, and bring infrastructure and resources in place to meet the user need. Similar studies have been conducted on the scientist community abroad in the field of science and technology. In comparison to the present study, it is found that the researchers in the field of S&T are yet to fully adopt a culture of open science as there is a lack of RDM knowledge and skill[5,10,12,14,15,20]. However, researchers are willing to share their data[16,31] interested in educating about RDM and gaining skills for good scientific practice[19-20]. Data sharing among the individual scientists by personal request is a common practice[10,13], apprehension for data loss is indicated[3] and repositories with long term preservation for continued access are welcomed by the scientists[2]. The library as a support mechanism in the research process is positively accepted by the scientist community and indicates a need for RDS from the library[5,28].

7. LIMITATIONS

This study has limitations in terms of the actual status of the researchers in CSIR, as only 19 laboratories were covered because only the participating libraries in the first stage of the research were included in the study. The domain coverage is also not uniformly represented with one cluster domain being unrepresented *i.e.,* Information Sciences due to a lack of participation. A major limitation is that personal communication with the researcher was not conducted, such as in the interview method, which resulted in a lack of in-depth discussion with the researcher. Additionally, there was no pre-sensitisation of the researchers; therefore they might not have fully understood the questions, as they were not familiar with the concepts, according to the feedback received.

8. CONCLUSION

This study highlights the current status of RDM among CSIR researchers, including data storage, data sharing and use of data which has put CSIR RDM in discussion. It has significant social and practical implication in the context of contemporary scientific research. Adherence to FAIR data principles is a societal imperative as open science and data transparency calls for research integrity, public trust, and global collaboration. This study finds a widespread lack of awareness and RDM among CSIR researchers which raises significant concern and without intervention; it will impede data sharing, reproducibility, and also hinder research collaboration. The study also identified a critical gap in the current research infrastructure which is the lack RDM support mechanisms and absence of adequate training. The urgent need for institutional support is highlighted through researchers' willingness to share data and profound interest in receiving RDM training and services. Libraries are well-positioned in bridging this gap through training programs and delivering tailored RDM services. The findings can be used as a basis for CSIR libraries to develop RDM services and put infrastructure in place conducive to researchers' needs for the FAIRification of research data. This will support researchers and empower them with the knowledge and tools to effectively manage their data in alignment with FAIR principles. It will ultimately contribute in advancing science and society by enhancing research quality, enable compliance with funding requirements, and ensure long-term data preservation and reuse. To achieve this, the study recommends that the library take a leading role in initiating RDM discussions with higher authorities to formulate appropriate RDS suited to the research domain by conducting intensive discussions with researchers, up skilling library staff, liaising with other units in the research ecosystem,[31-34] re-visiting existing infrastructure, and upgrading it as required. Studies such as this are crucial for the development of the open science movement in the field of S&T, a major gap identified in the literature in the Indian context. The study can be replicated to examine other S&T research institutions in India, with a

particular focus on those under the Department of Science and technology, GoI. Additionally, future research could be carried out to create a model for RDS based on the research ecosystem, with intuitive knowledge map of RDS.

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