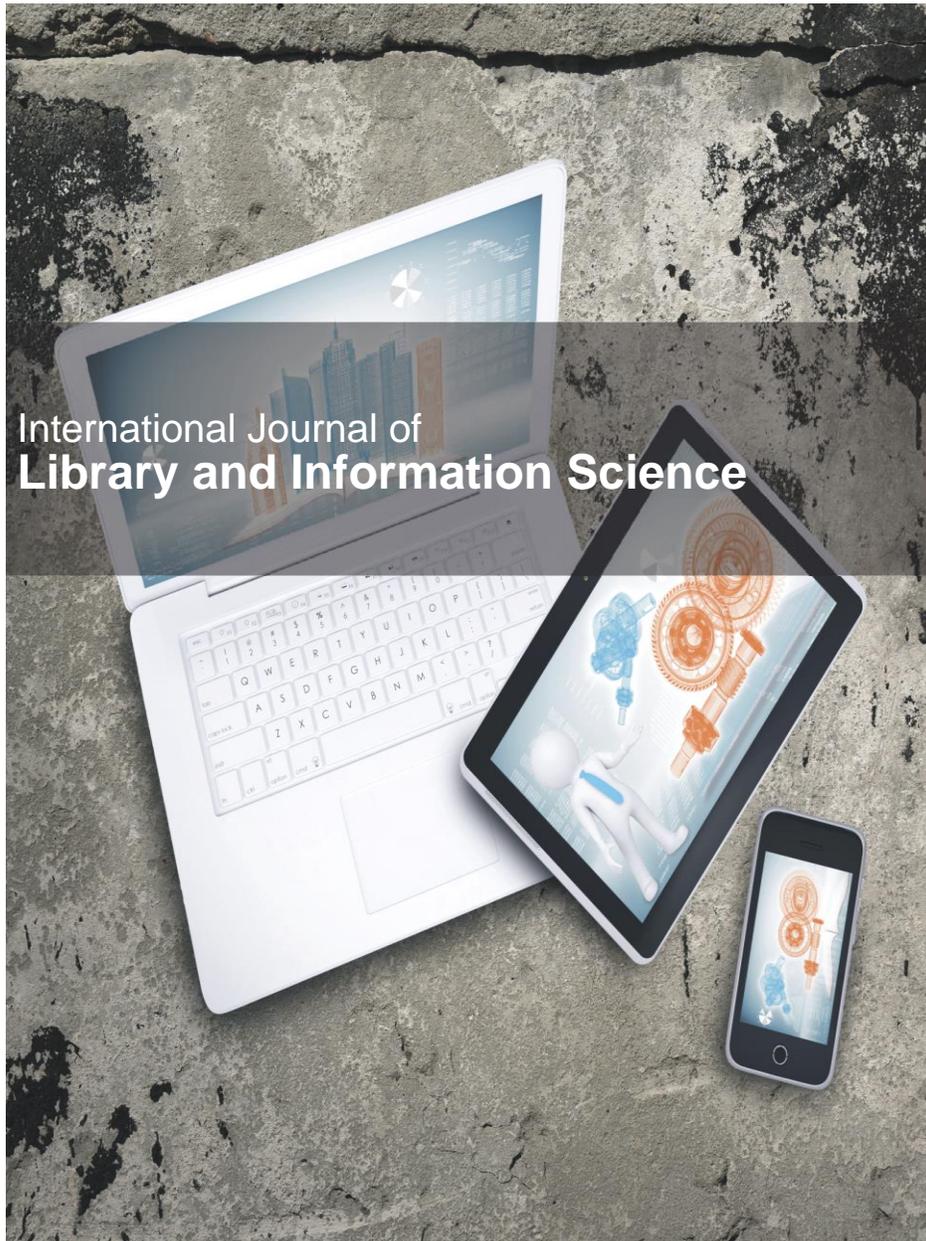


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Table of Content

The shortcomings of artificial intelligence: A comprehensive study	13
Stevie A. Burke* and Ammara Akhtar	
Biobibliometric portrait of Dr. Dilip Mahalanabis, pioneer of oral rehydration solution (ORS), the life-saving solution	31
Susanta Koley	

Full Length Research Paper

The shortcomings of artificial intelligence: A comprehensive study

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Artificial intelligence is considered one of the highly disruptive innovations of the 21st century that has garnered the enormous attention of the global community. Artificial Intelligence (AI) provides unprecedented widespread opportunities for revolutionizing and upgrading the infrastructure of various industries. It is one of the faster-growing go-to technologies for global industries allowing personalized experiences for all individuals. This disruptive technology is evolving and getting smarter daily, offering unique and incredible applications, including robots, facial recognition, customized user experience, language comprehension, voice assistant, and autonomous vehicles. In this study, various challenges regarding implementing AI in diverse fields of human lives were discussed. Indeed, AI is a long-standing controversial topic and is sometimes illustrated negatively. In an ongoing debate, some would refer to it as a blessing in disguise for businesses and industries. In contrast, others would refer to the artificial intelligence technology as an endangerment to the existence of humans due to its potential ability to take over and overpower humankind.

Key words: AI, Artificial intelligence, Robots, ChatGPT, Machine learning.

INTRODUCTION

During the last few years, the evolution of AI technology has certainly attained significant achievements, and deep understanding is one of its distinguished manifestations (Figure 1). AI is defined as a machine's ability to perceive, synthesize, and perform actions that lie within the range of human intelligence. The most prominent aim of AI is to program computers to mimic humans and do their work. AI is usually undertaken in combination with machine learning and data analytics. AI is being used to automate processes across many industries, including finance (Culkin and Das, 2017), tourism (Li et al., 2019), education, information systems (Chi et al., 2020), marketing, and healthcare. It is

responsible for incorporating fresh vitality into digital businesses by facilitating the development of intelligent devices and promoting the digital revolution. According to a report, it is stated that approximately 70% of world organizations will transform their digital strategies by developing AI infrastructure in the future (Goasduff, 2021).

AI can alter the interaction between different businesses and their customers (increasing productivity and improving effectiveness), thereby maximizing business profit. Online companies adopt chatbots to offer their consumers full-time services (Luo et al., 2019). AI-based robots are employed to assist

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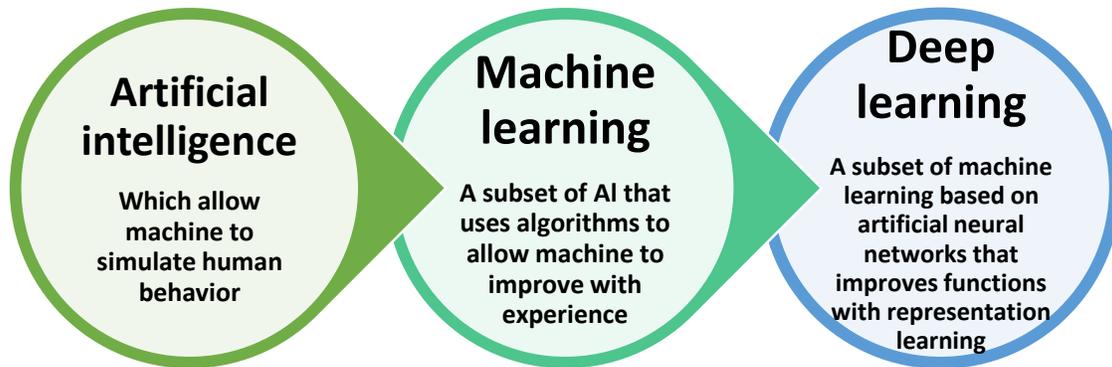


Figure 1. The difference between AI, machine learning (ML), and deep learning (DL).
Source: Jenis et al., 2023

customers in selecting the right products. In the healthcare system, artificial intelligence-based diagnostic systems allow rapid medical imaging, improved treatment planning, and faster diagnostics (Ploug and Holm, 2020). In the transportation industry, the manufacturing of autonomous vehicles has grabbed massive attention from different sectors (Radhakrishnan and Chattopadhyay, 2020). Additionally, AI-based technologies, including deep learning, voice assistant, facial recognition (Xu et al., 2021), image processing, personalized learning, and language translation, are bringing convenience to various aspects of human lives (Bhutoria, 2022). Despite these advantages, AI can potentially induce numerous negative consequences at different individual and organizational levels (Alt, 2018; Cheng, 2022). Currently, the positive features of AI are receiving massive attention, while little is paid to the negative ones.

Considering the availability of limited research on the downsides of artificial intelligence, this study was conducted to provide insight into the dark realm of AI and encourage the researchers to study and explore the risks associated with using artificial intelligence. AI undoubtedly has the potential to bring technological innovation in numerous contexts, but we should not overlook the detrimental consequences associated with using AI (Floridi et al., 2021).

THE SHORTCOMINGS OF AI

Artificial intelligence is omnipresent, and the belief of it becoming hostile against us is not new, as history is full of warnings ranging from famous sayings like the one by Elon Musk that "AI is far more dangerous than nuclear weapons" (Castagno and Khalifa, 2020). Stephen Hawking's said that "the progressive development of complete AI could fully demolish the human race as this disruptive technology has the potential to fully re-design

itself at a constantly increasing rate, while humans that exhibit steady biological evolution rate would not be able to compete and therefore could be potentially superseded" to the bulk of movies signifying the danger of AI turning from a faithful companion to an evil enemy (Curchoe and Bormann, 2019). Artificial intelligence has different cons, including high costs to create machines that mimic humans, inability to think outside the box (lacking creativity), displacing human occupations with robots, promoting human laziness, and the bulk of others. From the societal perspective, artificial intelligence is yielding various dark impacts ranging from data security to privacy issues, ethical problems, and workforce replacement (Dwivedi et al., 2021) (Figure 2).

Data bias

AI has the potential to integrate the bulk of data and modify it in a way that leads to the development of selection tools, AI-based predicted models, and pattern recognition. However, unfortunately, the AI-based science of "bulk data" employing computational strategies of big data sets to recognize unique patterns and connections has significant challenges. These challenges include data bias, data accessibility problems, data security, and ownership issues. The algorithms used in ML go through a training phase and is dependent on sufficient data input. Any systematic errors or inexactness during the steps of DL can substantially cause bias amplification or the absolute disregard of specific kinds of data. For instance, in the healthcare field, if the data in the training stage only includes embryos selected for transfer, the training dataset will not be representative of the entire embryo dataset that it is supposed to be used on later. This can induce data bias in the embryology laboratory (Curchoe and Bormann, 2019).

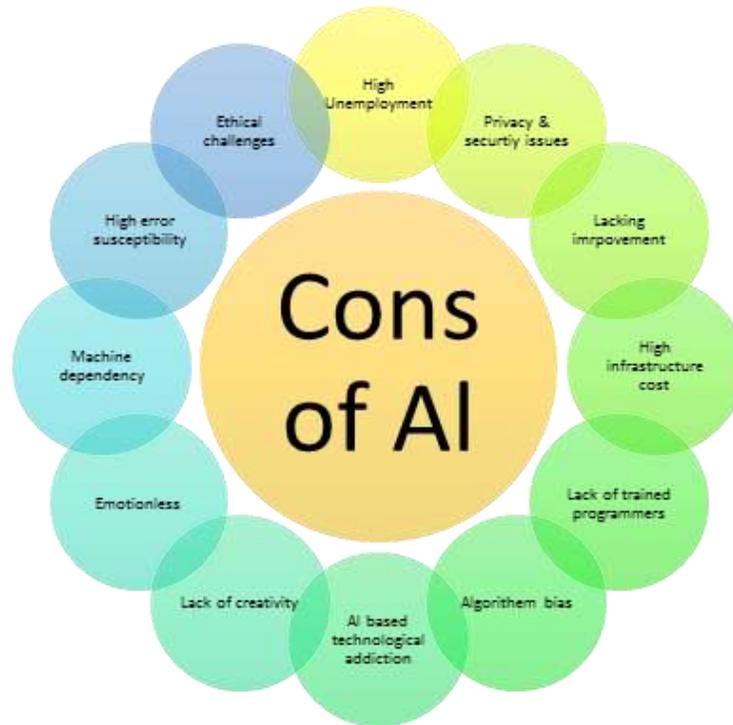


Figure 2. The cons of AI.
Source: Authors

AI carbon footprint

The carbon footprint of AI is another emerging and debatable ethical concern related to artificial intelligence technologies, with a truly global dimension. The increasing prevalence of artificial intelligence technologies has brought about a growing apprehension regarding the AI carbon footprint and its potentially devastating impact on global warming. The emission of greenhouse gases (GHG) is driven by the electricity and computational resources required to train AI models using machine learning methods (Tamburrini, 2022). Strubell et al. (2019) conducted a study to calculate the carbon footprint of training an AI-based model in "Natural language processing" (NLP). They reported that the training of this AI-based model could potentially emit greenhouse gases equivalent to those emitted by five automobiles. Furthermore, it has been noted that the estimated carbon footprint varies based on factors such as location, overall demand, and global disparities in power sources. For instance, the training of the AI-based model "BERT" was found to release approximately 22-28 kg of carbon dioxide in a US data center, which is twice the amount of emissions generated by conducting a similar experiment in Norway (Gibney, 2022).

Failure of chatbots

AI technology has been widely employed as a problem-

solving tool that provides high efficiency and increased effectiveness. Recently, a chatbot named Chatbot" ChatGPT has been gaining widespread attention from people around the world. ChatGPT is an AI-based chatbot developed with the latest version of OpenAI and launched at the end of 2022. Although there is much hype globally, in practice, like any other chatbot, these AI-based chatbots have raised several disadvantages, including lack of expression, no feelings, lack of insight, divergence, and inaccuracies (Susnjak, 2022). Hence, AI-based chatbots are not working as intelligently as people expect. For instance, a recent report based on FB project M presented by Griffith (2018) showed that 70% of the interactions between AI and humans failed. Another piece of information submitted by Forbes showed that approximately 80% of the customers that use e-commerce websites are reluctant to communicate with AI chatbots since they cannot perceive their actual needs (Forbes, 2021).

High error susceptibility

Personal virtual assistants (PVAs) are recently gaining significant popularity and becoming a prominent feature of mobile devices. Contrary to its growing use in the private context, the persistent implementation of PVAs at the organizational level has experienced widespread employee resistance. The execution of a specific task by using PVA on a smartphone device is quite simple but

somewhat complex at the corporate level (Adam et al., 2021). The employees in an organization can rarely act on their own as there is a kind of interdependent environment within an organization, and the failure of PVA can severely impact the organization at many levels (such as, financial loss). Moreover, the fear of job loss is another significant factor in employee resistance to PVAs. The prospect of PVAs causing confidential data leakage is one of the fundamental reasons for mistrust among individuals working in large organizations. Hornung and Smolnik (2022) designed a framework to study the role of artificial intelligence in invading the workplace and found the presence of negative emotions and dissatisfaction among employees regarding using PVAs at an organizational level.

Privacy and security concerns

At the individual level, the adverse effects of artificial intelligence are generally reflected in exacerbating privacy concerns. AI has the potential to get deep insights into the lives of users, thereby significantly inducing significant privacy risks. The electronic marketing industry uses AI for content and product recommendations (Grewal et al., 2021). Dickson (2019) reported that AI-based voice assistant like Alexa has the potential to predict the status of an ongoing relationship between a consumer with a marketer by analyzing the tone of voice of the consumer. A recent study by Seo et al. (2022) reported that consumers are still hesitant to use voice assistants for online shopping due to privacy issues. AI-based facial recognition for online payments can induce numerous privacy risks because the human face can reveal much personal information like age, gender, and appearance. Moreover, online recommendations based on previous searches and personal experiences can eventually lead to privacy concerns and perceived information narrowing. Therefore, people are often reluctant to rely on these technologies (Li et al., 2021).

Promoting addictive behaviors

Due to its growing demand in the tech industry, the term "addictive" is observed as one of the greatest compliments given to an artifact. Due to the emerging paradigms based on AI-based technologies, the importance of research connected with addictive digital behaviors is also evolving. Current research focuses on exploring the approaches and methods used by tech companies that ultimately lead to addiction (Ferreri et al., 2018). The development of novel AI-based designs has been reported to be responsible for promoting addictive technology that is growing massively and becoming harder to resist. Moreover, AI and concomitant ethical

debates bring novel perspectives on these addictive designs. AI-based algorithms have the potential to reshape the various aspects of human lives. With the development of novel algorithms capable of learning every user's experiences, habits, and schedules, addiction is expected to be attained at a comprehensive level along with sufficient granularity (Berthon et al., 2019). These addictive properties are generated by machine learning's ability to optimize the computable measures of engagement (Fourcade and Johns, 2020). According to a health standpoint, the excessive use of the internet, binge-watching of videos, obsessive use of social media, and problematic online game playing are some behaviors that can be assumed addictive (Burke et al., 2022). This so-called addiction induced by technology is now recognized as a proper health disorder (Vahia, 2013).

From an economic perspective, the growing need for these addictive technologies can be correlated with the new business models developed to capture and retain the user's attention (Bhargava and Velasquez, 2021). Diverse business companies and manufacturers widely employ AI-based algorithms to promote their services and various available products. For instance, these AI-based business strategies can be considered responsible for the exposure of adolescents and adults to content (either in the form of images, videos, or texts) related to pro-substance use, which has been further reported to be associated with high chances of substance use or substance addiction among those individuals (Burke et al., 2022). Indeed, addictive behaviors are becoming more common due to these addictive technologies. Furthermore, it would not be wrong to say that as our ability to detect addiction by using technology grows, so does our capability to substantially develop software and create experiences that progressively lead to addiction.

Promoting dark patterns

As these technologies are relatively emerging, different addictions are also being identified. The strategy used for gaining such user experiences includes using numerous sophisticated deceptive techniques to deliberately turn the knowledge collected from the users ultimately against them, also known as "dark patterns." These patterns are generally user interfaces intentionally developed by the designers to purposely manipulate or confuse the users by making it complicated for the users to demonstrate their actual preferences (Luguri and Strahilevitz, 2021; Waldman, 2020). For example, a video app called Tik Tok is developed to collect information about its users, including the content they watch, their caption, their location, the total time of use, and even the emotions that the video will develop. This bulk of data is consequently employed to do large-scale

collaborative filtering and developing links that surpass human abilities, thereby giving a unique experience to each user that complements the neurodiversity of every individual user and makes it more addictive (Zhao, 2021). Famous social websites like YouTube, Facebook, Instagram, and others employ similar algorithms and AI-based engines. Mentioned above are some of the ways developed by artificial intelligence to make users more addicted. Although the harms caused by these AI-based designs on the users are apparent, tech companies continuously design such experiences to be more irresistible (Sin et al., 2022).

High rate of unemployment

Business organizations face significant challenges in successfully executing artificial intelligence strategies in their current business models. Moreover, they have failed to address the grave problem of how this technology will impact the human workforce. One of the most significant alarming concerns of AI is its potential to cause large-scale human unemployment globally, and this mass unemployment is not only expected within e-commerce, but as this technology is rapidly evolving, this could enormously impact global labor markets and eliminate jobs in all walks of life (Danaher, 2019). Though this argument might sound satirical, it is relatively instructive in the sense that it illustrates the idea of how the rise of AI can have an impact on the human world.

CONCLUSION

Artificial Intelligence has been around for many decades, but it has been evolving rapidly and recently sparking primary interest among business enterprises, widely becoming one of the hottest trends of 2023. As with every emerging technology, AI is also a source of excitement and skepticism. Artificial intelligence has several challenges, and people are expressing their anxiety and dissatisfaction over the prospects of AI, wreaking havoc in the lives of humans. Undoubtedly, the impact of artificial intelligence on the global industry is irrefutable, and the most significant role humans can play in this perplexing situation is to ensure that this technology does not get out of hand. There is a dire need to improve artificial intelligence literacy and upskill to get the most out of it. Moreover, there is a need for more research to overcome numerous challenges before we can admit the immense transformational potential of this emerging technology.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Biobibliometric portrait of Dr. Dilip Mahalanabis, pioneer of oral rehydration solution (ORS), the life-saving solution

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Dr. Dilip Mahalanabis is a medical cum clinician scientist and globally celebrated pediatrician for his epoch-making discovery of ORS (Oral Rehydration Solution) in diarrhea and allied research. He is recognized as the “Father of ORS or Pioneer of ORS.” This biobibliometric study is based on his 233 publications contributed during 1970 to 2022, nearly during 53 years, including service and retirement period and shows various aspects of his career. From the collected bio-data and bibliographic-data, this study identifies year wise growth of research publications, authorship patterns, author productivity, research team and co-authors, leading collaborative authors, scattering of publications in various national and international communication channels, his most notable journal, and relationships with Degree of collaboration. It counts citation growth rate according to citation received in different abstracting and indexing journals. It also examines that the data set follows Lotka’s Law and Bradford’s Law.

Key words: Biobibliometrics, bibliometric, citation growth rate, Dilip Mahalanabis, oral rehydration solution, ORS, oral rehydration therapy, ORT, oral saline.

INTRODUCTION

‘Necessity is the mother of invention’ that means any invention comes from its necessity, that is, the people’s needs for solving problems. There are so many inventions either small or big starting from alpin, needle, safety pin to aero plane, train, rocket, etc. which are used by/ for the people to solve their needs. Invention whether it is small or big does not matter, but its value of the effectiveness/ usefulness should be evaluated. Oral Rehydration Solution, shortly ORS (oral saline) is a simple, effective remedy for dehydration (Journals of India, 2022) that can save a life and give re-birth one’s

life, that is, a life-saving solution. Nowadays, most of the families keep ORS as one of the necessary household items.

ORS (oral rehydration solution)

Oral rehydration solution (ORS), a mixture of salt, sugar and water, is used to treat dehydration caused by diarrhea, cholera and dysentery. Preparation process of ORS is well-known and simple to all of us (The

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Barthaman Partrika, 2022; Rehydration Project, 2014; Government of Canada (n.d). Anyone can prepare it at home for the diarrheal diseases.

Ready-made ORS packets are also cheaply available at medical shop or pharmacies, Government Hospital (free of cost) in almost all developing countries. It saved/ is saving millions of lives from life-killing diarrhea every year not only in India but all over the world. Yet, most of us do not know the name of its discoverer. He is being an Indian, Bengalee physician and medical scientist in cholera research, Dr. Dilip Mahalanabis, and his "ORS" is one of the greatest medical discoveries of the 20th Century (Journals Of India, 2022; The Barthaman Partrika, 202; Rehydration Project, 2014; Government of Canada (n.d).

Biobibliometric study is a quantitative analysis of the bio-data and bibliographical data of an author or a scientist, either living or dead. It includes all publications brought out during one's life time (Koley and Sen, 2006). This study highlights the various aspects of the career of a scientist and research publications, academic and scientific achievements such as his productivity according to his biological age, collaborative pattern, authorship status, rise and fall in the productivity curve, and other characteristics. All these may prove to be of great value to the concerned scientist, and are likely to increase the visibility of a good scientist, who is otherwise less known (Koley and Sen, 2006).

Many biobibliometric studies have been conducted in India. Of which more studies have been conducted by Kalyane alone or along with his co-author, and by other information scientists. These studies have covered both Indian and foreign scientists, Nobel laureates, film actress and others (Koley and Sen, 2006; Kademani et al., 2000; Banerjee and Chakrabarti, 2021; Nayak and Bankapur, 2017; Kalyane and Sen, 1996; Kalyane, 2005; Hugar and Mallappa, 2023; Savanur, 2017; Kalyane and Sen, 2002; Das and Bhattacharyya, 2021 Gholampour and Noruzi, 2021; Kalyane et al., 2001; Kavya et al., 2020; Kumar et al., 2018; Mondal et al., 2018; Kalyani and Sen, 1998; Koganuramath et al., 2003; Koley and Sen, 2017; Ruhela and Kumar, 2022; Koley and Sen, 2014a, b; Koley and Sen, 2021; Mahemei, 2023). This paper is the first attempt to present a biobibliometric study of the world famous Bengalee scientist and pediatrician, Dr. Dilip Mahalanabis.

Brief biographical sketch

Dilip Mahalanabis was born on November 12th November 1934 in Kishoreganj district, Bengal Province (undivided Bengal), British India (now Dhaka Division, Bangladesh). He attained his primary as well as secondary education from Kolkata. At the time of partition, he came to West Bengal. Then, he lived in Baranagar, later in Serampur, Hooghly and he spent his last life at Salt Lake, Kolkata,

and West Bengal. Mahalanabis was married to Jayanti Mahalanabis who died on the 9th of July in 2021. Dr. Mahalanabis also passed away on 16th October, 2022 at the age of 88 years (Vanshika, 2022; Sen and Manna, 2022; Mahalanabis, 2022). After completing his MBBS degree in medicine and surgery from the Calcutta Medical College under the University of Calcutta, West Bengal, India in 1958, he took training in Pediatric Medicine in this college and joined there as house staff in the department of Pediatrics. In 1960, he joined in The National Health Service (NHS) in UK and completed DCH (Diploma in Child Health) from London. At the age of 28, he was the first Indian who appointed as registrar in Queen Elizabeth Hospital for Children, London in 1961 (Mayor, 2023). In 1962 he did his MRCP degree from the Royal Colleges of Physicians and Surgeons, London, Edinburgh (Bagcchi, 2023; Staff Reporter, 2022). He was also elected as Fellow of that Royal Colleges (FRCP) (Sen and Manna, 2022).

Research contributions

Mahanalabis's research activities has spanned more than 50 years in the field of Oral Rehydration Therapy (ORT) including Oral Rehydration Solution (ORS) and published 233 papers during 1970-2022. After return from abroad, in 1966, he started his research work on early development of ORT as a research investigator in John Hopkins University International Centre for Medical Research and Training (JH-CMRT) in Calcutta. Though John Hopkins University selected *Infectious Diseases and Beliaghata General Hospital, Kolkata* as a research Centre for its application in large number of children with cholera patients available there (Sen and Manna, 2022; Bagcchi, 2023; Hasi Majumdar Memorial Lecture, 2014; Subhajoy, 2022). It should be mentioned that Dr. Shambhu Nath De (popularly known as S. N. De), a Bengalee doctor and the pioneer in cholera research (Koley and Sen, 2014a) had shown in his research Dr Mahalanabis demonstrated that cholera bacteria secrete enterotoxin in the intestine; that helped in the development of new vaccines by the Southeast Asia Treaty Organization (SEATO)-Pakistan Cholera Research Laboratory. Cholera is an infectious disease; while blood vessel disease is a type of vascular disease affecting the arteries and veins that carry blood to and from the arms, legs and abdomen. In this regard, he had pointed out the efficacy of ORS experimentally.

Dr. Mahalanabis examined it that the cholera is cured using mixture of salt-sugar-water (that is, oral saline) as the substitute of intravenous saline. Based on that intellectual concept, Dr. Mahalanabis became the one pioneer of ORS who established largely necessity and the high effectiveness of ORS (Staff Reporter, 2022; Subhajoy, 2022) by applying it among a large number of diarrhea patients. It is a matter of pride that two Bengalee doctors were behind the oral saline, ORS.

Research limitations

Dr. Mahalanabis faced different obstacles for his research work. As there are no sufficient cholera patients in his research Centre, *Infectious Diseases and Beliaghata General Hospital, Kolkata* was selected for application of his formula.

It should also be noted that, despite his treatment going successfully in a refugee camp in Bongaon, some members of the scientific community made negative comments on his work. Furthermore, many journals refused to publish his original paper on oral rehydration therapy as an effective treatment for dehydration caused by diarrhea and related diseases. He published after three years the war ended by December 1970 (Mahalanabis et al., 1974). He never patented his ORS formula (Mahalanabis, 2022).

Research implications

It was the time of the 1971 Bangladesh Liberation War. Once cholera took a massive outbreak among the millions of Bangladeshi refugees who sought shelter in a refugee camp in Bongaon, West Bengal, India. Due to an insufficient supply of intravenous saline, a death march began. In this situation, a young man of 37 years, along with his team, arrived at the camp and started treatment using his own prepared "Oral Saline," a solution of salt, sugar, and baking powder. That man was Dr. Mahalanabis, and the Bongaon camp was his first field trial of ORT among a huge number of patients. His treatment continued for nearly two months. He advised all the patients to drink this solution until they no longer felt willing to do so because a lack of desire to drink the solution was considered one of the signs of recovery (Sen and Manna, 2022; Bagcchi, 2023; Staff Reporter, 2022; News Desk, 2023). In other words, he convinced the cholera patients to drink "oral saline" until they felt hungry or till the time when their weakness would be no more. This way, many cholera patients were cured there and the death toll started to decline rapidly compared to other camps where "intravenous saline" was given to the patients (Subhajoy, 2022). Finally, the practical application of the ORS among huge number of cholera patients and its success proved that ORS is a most useful life saving solution for cholera and diarrhea as well as the substitute of intravenous saline. His formula of ORS was published in *John Hopkins Medical Journal* (1973) (Staff Reporter, 2022). After that, World Health Organization (WHO) gave recognition to his ORS formula.

Future research

The Society for Allied Studies (SAS) in Kolkata, West Bengal carries on the future research in the path of Dr.

Mahalanabis. Later, it designated as a WHO Collaborating Centre for Child Health. According to the guidelines of the SAS, "Purulia Model of Sick Newborn Care Unit" with the help of UNICEF and district level administrative body of West Bengal government is doing works to minimize neonatal mortality rate and similar models have been established in different developing countries by UNICEF.

Professional career

From 1975 to 1979, Mahalanabis worked in cholera control for the World Health Organization (WHO) in Afghanistan, Egypt and Yemen (Mahalanabis, 2022). In the mid-1980s and early of 1990s, he was a medical officer of Global Program of Diarrheal Diseases Control of WHO and UNICEF with ORT (Vanshika, 2022; Bagcchi, 2023; Hasi Majumdar Memorial Lecture, 2014). Main objectives of this programme were to attend in discussions in different countries over the world and prove the efficacy of the use of ORS and promote prevention measures that it could save millions of lives among children globally and research in laboratories (Subhajoy, 2022). He joined WHO (Headquarter) in Geneva as a staff member in 1983 for promoting ORT globally, particularly for its acceptance by both the Pediatricians and the general people. In 1988, Mahalanabis worked at International Centre for Diarrheal Disease Research, Bangladesh in Dhaka, an International Health and Population Research Centre, as the director/ head of Clinical Sciences Division and led a large research division for 7 years. A team of scientists was conducting clinical and nutrition research on public health importance under his leadership (Hasi Majumdar Memorial Lecture, 2014). In addition, he was affiliated with National Institute of Cholera and Enteric Diseases (NICED), Beliaghata, Kolkata. He also worked as a visiting teaching faculty of pediatrics in the Institute of Child Health (ICH), Park Circus, Kolkata. Dr. Mahalanabis donated one crore rupees from his savings and earnings to the ICH Hospital and there is ward in his name (Sen and Manna, 2022; Staff Reporter, 2022). The Society for Allied Studies (SAS), was established in 1990 by him in Kolkata, West Bengal. Later, it designated as a WHO Collaborating Centre for Child Health. The SAS along with Dr. Mahalanabis has developed "Purulia Model of Sick Newborn Care Unit" with the help of UNICEF and district level administrative body of West Bengal government to minimize neonatal mortality rate and similar models have been established in different developing countries by UNICEF (Sen and Manna, 2022; Bagcchi, 2023; Staff Reporter, 2022; Subhajoy, 2022).

Awards and honours

In 1994, Mahalanabis elected a member of the Royal

Swedish Academy of Sciences which is directly responsible for awarding three of the six categories of Nobel Prizes. He, along with Dr. Nathaniel Pierce, Dr. David Nalin, and Dr. Norbert Hirschhorn, was awarded the Pollin Prize (considered equivalent to the Nobel Prize in Pediatrics) for his contributions to pediatric research and the discovery of Oral Rehydration Therapy in 2002 by Columbia University, USA. Mahalanabis, along with Dr. Richard A. Cash and Dr. David Nalin, received the Prince Mahidol Award in 2006 from the King of Thailand in the field of Public Health for his development and implementation of Oral Rehydration Therapy.

He got *D. Sc (Honoris Causa)* from the Vidyasagar University, Medinipur, West Bengal, India in 2012 and from University of Calcutta, West Bengal, India in 2019 (Sen and Manna, 2022; Hasi Majumdar Memorial Lecture, 2014; Mayor, 2023). In the same year, he was honored with the *Barclay Memorial Award* from Asiatic Society of Kolkata, West Bengal, India. During Covid pandemic, in 2020, a seminar hall was launched by him in ID and BG Hospital building, Beliaghata, Kolkata which was dedicated to his name. He recently was also awarded the *Padma Vibhushan* (posthumous), India's second highest civilian award by Government of India, in 2023 for widely use of his ORS, and over 5 crore lives were saved globally according to a government release. Dr. Mahalanabis took memberships from different academic societies namely American Society of Nutrition, Nutrition Society of India, and Indian Academy of Pediatrics (Sen and Manna, 2022; News Desk, 2023).

Materials

This study is confined to 233 publications of the medical as well as clinician scientist published during his life time. His publications include research article published in different national and international journals, conference proceedings, books, reports and letters, etc., mostly on clinical and nutrition research in respect to community health care, during 1970-2022.

Objectives

The main objectives of the study are:

- (a) To find out the year-wise distribution of authorship pattern;
- (b) To determine the position of Mahalanabis as main author and co-author;
- (c) To measure the degree of collaboration (collaboration coefficient);
- (d) To calculate author productivity;
- (e) To observe age wise publication pattern;
- (f) To identify the research team with co-authors
- (g) To find out peak period of productivity;

- (h) To observe rank-wise scattering of publications;
- (i) To identify the papers published at national and international levels;
- (j) To count citation received and Citation Growth Rate
- (k) To examine the Lotka's Law for Co-authors
- (l) To test Bradford's law for communication channels.

METHODOLOGY

Lists of publications of Mahalanabis were collected from Dr. Hemanta Koley, Deputy Director, Niced, Kolkata, one of the co-authors of the scientist; Research Gate, Google Scholar and PubMed databases. In addition, other data has been accumulated from several offline and online sources. A compiled list of 233 publications of Dilip Mahalanabis was prepared for this study. The collected data were transferred into MS-excel and Words and tabulated. Then, the present study investigates authorship pattern, main authors and co-authors, author productivity and research team from 233 papers. Various others facts such as collaboration coefficient, age wise publication pattern, peak period of productivity, rank-wise scattering of publications at national and international levels, Citation Growth Rate count are generated. In addition, it has also been examined whether the data sets are being followed Lotka's Law and Bradford's law or not. Finally, on the basis of the data, results are discussed in the following sections.

DATA ANALYSIS AND DISCUSSION

Authorship scenario

In 233 publications of Mahalanabis, three papers (two five-authored and one six-authored) have been published in 1970. A largest number of papers that is, 26 and 21 various-authored papers were brought out in 1995 and 1998 respectively. There are 13 mega-authored publications, and one is 19-authored paper. The highest number of authors is associated with the paper in the year 1996. Multi-authored publications reveal that he carried out team research.

Table 1 shows year-, age- and authorship status- wise distribution of papers of Mahalanabis along with degree of collaboration. In 233 publications published by Mahalanabis, he is the first position as author in 33 papers, second position in 68 papers, third position in 30 papers, fourth position in 28 papers, fifth position in 23 papers, sixth position in 18 papers, seventh position in 14 papers; eighth position in 3 papers, ninth and tenth position in 2 papers each and more than tenth position in 3 papers. In all, he has published 191 publications as co-author. It is interesting to note that he produced the largest number of publications that is, 68 as second author and the number of publications as first author that is, 33 ranks second. His publications as 3rd, 4th and 5th author are also considerable. Mahalanabis's first publication appeared when he was 37 and his productive life spanned 53 years. Surprisingly, he has no publication in 1971 when he was busy for the treatment in refugee camp in Bongaon during the outbreak of cholera among

Table 1. Year, age and authorship status wise distribution of papers of Mahalanabis.

Year	TAP	CAP	AA	PPA	SAP	MAP	Authorship position (P)										CoA	DC		
							P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈	P ₉	P ₁₀			>P ₁₀	
1970	3	3	37	1		3	2	1											11	1.00
1972	1	4	39	3		1	1												03	1.00
1973	1	5	40	4		1	1												04	1.00
1974	1	6	41	5		1	1												04	1.00
1975	1	7	42	6		1		1											03	1.00
1976	1	8	43	7		1	1												04	1.00
1977	3	11	44	8		3	1	2											06	1.00
1978	3	14	45	9		3		2	1										08	1.00
1979	6	20	46	10		6	4	2											10	1.00
1980	2	22	47	11	1	1			1										04	0.50
1981	1	23	48	12	1														-	0.00
1982	3	26	49	13		3		3											04	1.00
1983	4	30	50	14	1	3	1	1			1								07	0.75
1984	3	33	51	15	1	2		1	1										07	0.67
1986	1	34	52	17		1		1											05	1.00
1987	1	35	53	18	1														-	0.00
1988	1	36	54	19		1			1										03	1.00
1989	1	37	55	20		1		1											02	1.00
1990	1	38	56	21	1														-	0.00
1991	3	41	57	22	1	2	1						1						10	0.67
1992	6	47	58	23		6	2	1	1		1	1							22	1.00
1993	7	54	59	24		7	2	2	1		1		1						24	1.00
1994	16	70	60	25		16	1	5	6	1	2	1							34	1.00
1995	26	96	61	26		26	1	8	4	6	3	3	1						65	1.00
1996	18	114	62	27	1	17	2	6	2	1	1	2	2					1	67	0.94
1997	16	130	63	28		16	1	4	2	2	1	1	4	1					53	1.00
1998	21	151	64	29		21		2	5	3	4	3	2		1		1		61	1.00
1999	14	165	65	30		14		3	1	5	4							1	64	1.00
2000	6	171	66	31		6		1		1	2	1		1					31	1.00
2001	5	176	67	32		5	2	1		1							1		27	1.00
2002	10	186	68	33		10	2	3		2		1		1	1				47	1.00
2003	4	190	69	34	1	3		2				1							13	0.75
2004	7	197	70	35		7	1	2	1		1	1	1						32	1.00
2005	6	203	71	36		6		3		1	1		1						24	1.00
2006	7	210	72	37		7	3	2	2										28	1.00
2007	2	212	73	38		2		2											01	1.00
2008	5	217	74	39		5	1	3				1							32	1.00
2009	6	223	75	40		6	1	1		2		1	1						35	1.00
2010	4	227	76	41		4		1	1	1		1							11	1.00
2012	3	230	78	43		3	1			2									09	1.00
2014	2	232	80	45		2		1										1	20	1.00
2022	1	233	88	53		1					1								04	1.00
Total	233				9	224	33	68	30	28	23	18	14	3	2	2	3	799	0.96	

TAP= Annual Publication, CAP= Cumulative Annual Publication, AA= Author's Age, PPA= Publication Productive Age, SAP = Single Authored Publications, MAP= Multiple Authored Publications P₁ = author in 1st position; P₂ = author in 2nd position and so on; CoA = No. of Co-authors, DC= Degree of Collaboration = MAP/TAP.

refugees.

He also has no paper in 1985 when was engaged in

Global Program of Diarrheal Diseases Control of WHO and UNICEF with ORT to attend in discussions and prove

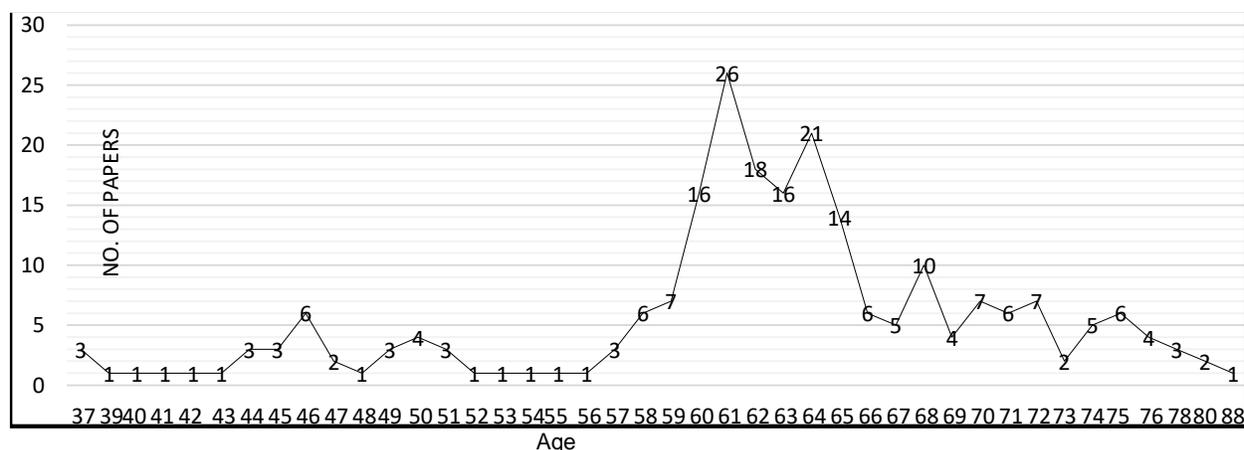


Figure 1. Variation of number of papers as per Age.

Source: Author

Table 2. Authorship pattern.

No. of authors	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12A	13A	15A	16A	18A	19A	TP
No. of non-collaborative papers	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
No. of collaborative papers		8	17	42	58	32	24	22	8	4	2	2	1	1	1	1	1	224

1A= one authored paper, 2A= two authored paper & so on. TP= Total Papers.

the efficacy of the use of salt-sugar-water mixture and promote prevention measures which saves millions of lives. There is no paper published by him in 2013 and during 2015-2021 (that is, 7 years). His productivity peaked in 1995 when he published 26 papers at the age of 61 (Figure 1). Besides, he also published second highest number of papers that is, 21 in 1998 at the age of 64. It is also observed from Table 2 that Mahalanabis published 30 (nearly 13%) papers only when he crossed 50 years of his age.

By 55, he had published 37 papers that were very less than 50% and at this time he was engaged with WHO programme with ORT application and usefulness of ORS globally. At the age of 60, he has 70 papers that is, 30% of his papers has been published. When he completed 63 years, more than 50% of his papers had been seen the light of the day. The largest number of papers that is, 178 (more than 76%) were produced in his retired life at the age 60-80.

During 2015- 2021, he could not publish any paper but in 2022, one paper has been published when he was 88 years old. His year- and age- wise publication pattern proves that Mahalanabis was continuously engaged in research activities on ORT in different laboratories globally. His single author paper has been first published in 1980 at the age of 47. It is also observed from Table 1 and Figure 1 that Mahalanabis contributed one

collaborative paper in the year 2022 he died at the age of 88.

Authorship pattern

Authorship pattern indicates the number of authors per paper. From Table 2, it appears that Mahalanabis has contributed only 9 papers without any collaboration during his entire productive career. All other publications that is, 224 are produced with collaboration. Of the collaborative papers, 57 are five-authored, 43 four-authored, 32 six-authored, 23 seven-authored, 22 eight-authored, 8 nine-authored, 4 ten-authored, 2 each eleven- and twelve-authored. In the initial years of the productive life of the author there was predominance of single-authored and two-authored papers. With passage of time, papers published by three or more authors started appearing and the trend culminated in mid-1990s and early -2000s with four authored to multi-authored papers.

Position in the byline of authors

The position of a scientist in the byline of the authors is an interesting field of the study. Table 3 shows

Table 3. Status of Mahalanabis in the byline of authors.

Publications	Status or position in the byline													Total	
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	18th		
Two-authored	4	4													8
Three-authored	3	6	8												17
Four-authored	5	18	7	12											42
Five-authored	10	21	6	6	15										58
Six-authored	3	8	2	4	4	11									32
Seven-authored	4	4	4		2	6	4								24
Eight-authored	1	3	4		2	3	6	3							22
Nine-authored		3				1		2	2						8
Ten-authored	1	1					1			1					4
Eleven-authored							2								2
Twelve-authored	1						1								2
Thirteen-authored												1			1
Fifteen-authored	1														1
Sixteen- authored										1					1
Eighteen-authored														1	1
Nineteen-authored											1				1
Total	33	68	31	22	23	21	14	5	2	2	1	1	1		224

Source: National Institute of Cholera and Enteric Diseases (NICED)
<https://www.indiascienceandtechnology.gov.in/organisations/ministry-and-departments/indian-council-medical-research-icmr/national-institute-cholera-and-enteric-diseases-niced-kolkata>

Mahalanabis' position in the byline of authors in his collaborative publications. He appears as the first author in 33 publications, which is a credit to his first authorship among numerous collaborators. He occupies the second position in as many as 68 publications, the third position in 31 papers, the fourth position in 22 publications, and the fifth position in 23 publications, and so on. He occupies 10th and <10th position in five papers. Out of mega-positions, he occupies eighteenth position in one paper. He has no paper as fourteenth-and seventeenth-author.

Non- collaborative papers

Mahalanabis produced the papers with collaboration at the age of 60-65, mostly after his retirement. Table 4 presents authorship pattern with the time span of collaboration. Five-authored collaboration has produced the largest number of papers, that is, 59 with the maximum time span of 53 years.

Four-author papers, 42 in total, were published in a time span of 38 years. Some papers took long time span in publishing such as first author 9 papers in a time span of 24 years, second author 8 papers in 28 years, nine author 8 papers in 16 years, ten author 4 papers in 10 years, eleven author 2 papers in 17 years, and twelve author 2 papers in 17 years. Mega-authored single four papers were published just in a time span of one year each.

Author productivity

The quinquennium publications data of Mahalanabis are presented in Table 5 and Figure 2. The highest contribution, identified as 95, occurred during 1995-1999 (age range 61 to 65), followed by 33 contributions during 1990-1994 (age 56-60), 32 contributions during 2000-2004 (age 66-70), and 26 contributions during 2005-2009 (age 71-75). The author was thus most active between the ages of 61 and 65 during the period of 1995-1999. Mahalanabis had no contributions during the age range of 81-85 (2015 to 2019). His least contribution was 1 at the age 86-90 (2020-2024), followed by 4 at the age 51-55 (1985-1989), 6 at the age 36-40 (1970-1974), and 9 at the age 76-80 (2010-2014). Usually, people experience physical and mental decline as they age. However, Mahalanabis was most active in research activities after retiring between the ages of 61 and 75 (1995 to 2009), and his level of activity gradually declined thereafter. It is notable that the author's productivity increased up to the age of 65.

Table 5 and Figure 2 give an idea about the productivity of the author and the period when his productivity peaked. In the first quinquennium of his active career, his productivity was 1.2 per year which slightly increased to 2.8 in the second quinquennium. In the next two quinquenniums, productivity started declining and dropped to 0.8. From the fifth quinquennium, it increased to 19 in 1995-1999, and thereafter, it gradually decreased to zero. In the last quinquennium, the year of

Table 4. Time span of authorship patter.

No. of authors (A)	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12A	13A	15A	16A	18A	19A
No. of papers	9	8	17	42	58	32	24	22	08	04	02	02	01	01	01	01	01
Time span (total)	24	28	32	38	53	40	33	33	16	10	19	17	01	01	01	01	01
Duration	1980-2003	1983-2010	1979-2010	1972-2014	1970-2022	1970-2009	1977-2009	1978-2010	1996-2008	1997-2006	1991-2009	1993-2009	1999-1999	2008-2008	2001-2001	2014-2014	1996-1996

Source: National Institute of Cholera and Enteric Diseases (NICED) <https://www.indiascienceandtechnology.gov.in/organisations/ministry-and-departments/indian-council-medical-research-icmr/national-institute-cholera-and-enteric-diseases-niced-kolkata>

Table 5. Quinquennium publications.

Quinquennium (year)	AA	PPA	APC	Productivity per year
1970-1974	36-40	1--5	6	1.2
1975-1979	41-45	6--10	14	2.8
1980-1984	46-50	11--15	13	2.6
1985-1989	51-55	16-20	4	0.8
1990-1994	56-60	21-25	33	6.6
1995-1999	61-65	26-30	95	19.0
2000-2004	66-70	31-35	32	6.4
2005-2009	71-75	36-40	26	5.2
2010-2014	76-80	41-45	9	1.8
2015-2019	81-85	46-50	0	00
2020-2024	86-90	51-55	1	0.2
Total			233	

Source: National Institute of Cholera and Enteric Diseases (NICED) <https://www.indiascienceandtechnology.gov.in/organisations/ministry-and-departments/indian-council-medical-research-icmr/national-institute-cholera-and-enteric-diseases-niced-kolkata>

his death, it slightly went up again. In the sixth quinquennium, when productivity peaked, Mahalanabis was the primary author in only one paper.

Authorship analysis

The name of the first authors and the co-authors are enumerated in Table 6. The ranked list of

names of the co-authors is enumerated in Table 8 including number of years taken for publishing paper and paper per year of a co-author shown in the fourth and fifth columns respectively.

The top-ranked co-author is George Fuchs (co-authored 33 papers in 6 years, nearly 5 papers per year), the most productive collaborator of Dilip Mahalanabis, followed by Mardjan Wahed who co-authored 26 papers over 15 years (nearly 2 papers per year). The third, fourth and fifth ranked

co-authors are Kailash Jalan, P K Bardhan and A Faruque who contributed 23, 22 and 20 papers during 31, 9 and 8 years respectively.

Co-authorship and Lotka's law

Lotka's law is an empirical law of bibliometric study. Lotka's general equation for scientific productivity is " $x^n \cdot y = \text{constant}$ ". It indicates the

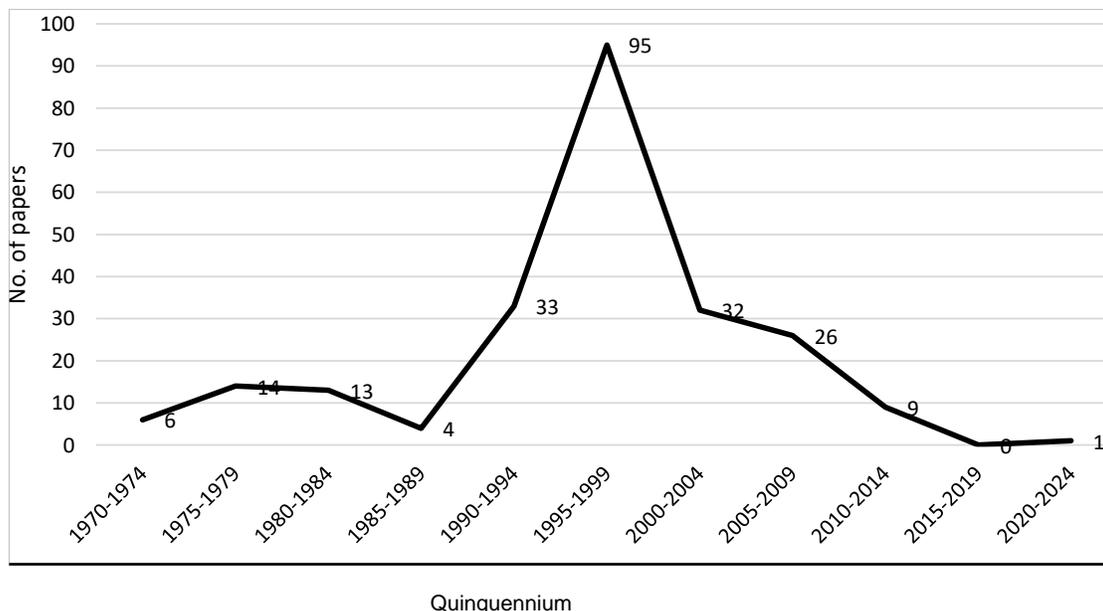


Figure 2. Peak period of publication of Mahalanabis.

Source: National Institute of Cholera and Enteric Diseases (NICED)
<https://www.indiascienceandtechnology.gov.in/organisations/ministry-and-departments/indian-council-medical-research-icmr/national-institute-cholera-and-enteric-diseases-niced-kolkata>

Table 6. Ranking of Co-authors.

Rank	PDM	Co-authors' names	PTT (years)	Paper / Year
1	33	Fuchs, George	06	5.50
2	26	Wahed, Mardjan	15	1.73
3	23	Jalan, Kailash	31	0.74
4	22	Bardhan, PK	09	2.44
5	20	Faruque, A	08	2.50
6	19	Kabier, Iqbal	13	1.54
7	17	Rahman, M	09	1.88
8	16	Islam, Mohammad	14	1.14
9	15	Albert, M; Khaled, Mohamma; Sarker, Shafiqul; Sen, A (04)	10, 13, 7, 33	1.50, 1.15, 2.14, 0.45
10	14	Maitra, T	31	0.45
11	13	Agarwal, S ; Hoque, Syada (02)	31, 9	0.41, 1.44
12	12	Gyr, K; Hossain, M; Patra, F (03)	7, 11, 20	1.71, 1.09, 0.60
13	11	Bose, Kaushik; Habte, D; Salam, Mohammed (03)	9, 4, 16	0.81, 2.75, 0.68
14	9	Bhan, Mohan; Fontaine, Olivier; Haider, Rukhsana (03)	18, 17, 8	0.50, 0.52, 1.12
15	8	Alvarez, J; Biswas, Rabi; <i>Chakrabarti, M</i> ; Mazumder, Ramendra; Rahman, Mohammad (05)	6, 8, 12, 8, 5	1.33, 1, 0.66, 1, 1.60
16	7	Akramuzzaman, S; Alam, Nurul; Beglinger, Christoph; Bhattacharya, Sujit; Bisai, Samiran; Chatterjee, A; Mitra, Amal; Shaikh, Saijuddin (08)	11, 7, 5, 25, 10, 9, 8, 9	0.63, 1, 1.40, 0.28, 0.70, 0.77, 0.87, 0.77
17	6	Ashraf, H; Bhattacharya, M; Brown, K; Haskell, M; Hildebrand, P; Jones, A; Kurpad, Anura; Peerson, J; Rabbani, G; Rahman, M; Sen, Bandana; Singh, Arun (12)	8, 17, 3, 4, 4, 4, 9, 4, 12, 4, 9, 5	0.75, 0.37, 2, 1.5, 1.5, 1.5, 0.66, 1.5, 0.5, 1.5, 0.66, 1.2
18	5	Alam, NH; Banerjee, P; Faruque, Shah; Hamadani, Jena; Islam, A; Islam, Sheikh; Khatun, Mousumi; Majid, Nuliana; Nair, G; Roy, Swapan; Sack, RB; Shoda, R; Som, Tapas; Wahed, Mohammad; Wahed, Mohammed (15)	10, 5, 7, 3, 6, 4, 4, 4, 17, 8, 30, 8, 5, 6, 8	0.50, 1, 0.71, 1.66, 0.83, 1.25, 1.25, 1.25, 0.29, 0.63, 0.16, 0.63, 1, 0.83, 0.63

Table 6. Contd.

19	4	Alam, Najah; Behrens, R; Bhandari, Nita; Black, Robert; Chakraborty ML; Dhar, U; Gupta, Susham; Handelman, Garry; Hasnat, A.; Khan, Wasif; Malek, M; Mondal, A; Pierce, NF; Santosham, Mathuram; Shaikh, Sara; Simpson TW; Sur, Dipika; Tomkins, Andrew (18)	2, 8, 6, 6, 29, 8, 5, 3, 4, 5, 3, 5, 35, 6, 7, 34, 15, 8,	2, 0.5, 0.66, 0.66, 0.13, 0.5, 0.8, 1.33, 1, 0.8, 1.33, 0.8, 0.11, 0.66, 0.57, 11, 0.26, 0.5
20	3	Bagchi, NG; Bandyopadhyay, Sudipta; Begum, Monira; Bhatnagar, Shinjini; Bhattacharya, AK; Biswas, Esther; Chakrabarty, Manilal; Choudhuri, AB; Clemens, John; Datta Gupta, Anupam; Datta, Nandini; Dibley, Michael; Dube, Brinda; Islam, M; Jacobs B; Jana, Shuvankar; Khaled, Mohammed; Khatua, S; Malek, Md; Mazumder, Sarmila; Taneja, Sunita (21)	12, 5, 2, 14, 12, 2, 2, 12, 6, 4, 4, 3, 6, 2, 5, 8, 7, 2, 4, 6, 6	0.25, 0.6, 1.5, 0.21, 0.25, 1.5, 1.5, 0.25, 0.5, 0.75, 0.75, 1, 0.5, 1.5, 0.6, 0.37, 0.42, 1.5, 0.75, 0.5, 0.5
21	2	Agarwal, RC; Ali, Mohammed; Ansaruzzaman, MohammadAwal, MA; Bagchi, D; Bahl, Rajiv; Bandyopadhyaya, S; Beltinger, J; Betinge, R; Bhan, Maharaj; Bhattacharya, Jayanta; Bhutta, Zulfiqar; Brayton, J; Chowdhury, A; Chowdhury, AKA; Desjeux, Jehan-François; Duggan, Christopher; Dutta, Dev; Eeckels, R; Ghosh, Amit; Goran, Michael; Gupta, A; Gyr, N; Hoque, Bilqis; Hossain, A; Hye, H; Islam, K; Islam, M; Islam, Mohammed; Islam, Moniul; Islam, Sirajul; Islam, Sufia; Kanungo, Suman; Khaled, Mohammad; Kumar, Ramesh; Lahiri, M; Ly, DT; Majumder, Rahul; Manna, Byomkesh; Matsueda, K; Meier, R; Mukherjee, KL; Mukhopadhaya, Arunika; Nandy, Ranjan; Paul, D; Pazhani, Gururaja; Pizarro Torres, Daniel; Rabbi, A; Rahman, AKSM; Rahman, ASM; Rahman, Md. Atikur; Rahman, Mohammed; Ramamurthy, Thandavarayan; Salaam, MA; Sarker, Sabbir; Sazawal, Sunil; Schneider, H; Siber, G; Singh, KD; Sinha, Anju; Snyder, JD; Thanh, PN; Thompson, Ciara; Thungapathra, M; Tzipori, S; Umeda, N; Unicomb, Leanne; Walther, R; Yamato, Shigeru; Zeitlyn, S; Zetterstrom, R (72)	3, 2, 4, 3, 2, 2, 2, 3, 4, 6, 5, 2, 14 3, 5, 2, 4, 4, 1, 5, 6, 3, 3, 2, 2, 6, 2, 7, 2, 2, 1, 5, 5, 7, 8, 2, 3, 6, 3, 7, 4, 4, 5, 4, 6, 5, 6, 4, 2, 6, 2, 1, 2, 6, 10, 3, 2, 4, 2, 6, 2, 14, 6, 2, 6, 8, 4, 4, 3, 4, 3, 7	0.66, 1, 0.5, 0.66, 1, 1, 1, 0.66, 0.5, 0.33, 0.4, 1, 0.14, 0.66, 0.4, 1, 0.5, 0.5, 2, 0.4, 0.33, 0.66, 0.66, 1, 1, 0.33, 1, 0.28, 1, 1, 2, 0.4, 0.4, 0.28, 0.25, 1, 0.66, 0.33, 0.66, 0.28, 0.5, 0.5, 0.4, 0.5, 0.33, 0.4, 0.33, 0.5, 1, 0.33, 1, 2, 1, 0.33, 0.2, 0.66, 1, 0.5, 1, 0.33, 1, 0.14, 0.33, 1, 0.33, 0.25, 0.5, 0.5, 0.66, 0.5, 0.66, 0.28
22	1(Each author)	179 single author	1 each	1 (For all authors)

Source: National Institute of Cholera and Enteric Diseases (NICED) <https://www.indiascienceandtechnology.gov.in/organisations/ministry-and-departments/indian-council-medical-research-icmr/national-institute-cholera-and-enteric-diseases-niced-kolkata>

relation between the frequency y of authors making x contributions. In a special case, when $n=2$, he described the meaning of the equation in simple way that: “*the number of persons making 2 contributions is about one-fourth of those making one; ...the number making n contributions is about $1/n^2$ of those making one, and the proportion of all contributors, that make a single contribution, is about 60%* (Hertzels, 1985)”, that is, 60 authors out of 100 will have one publication. In other words, it is to be said that out of all the authors, 60% authors will contribute just one publication, 15% authors will contribute 02 publications (that is, $1/2^2 \times 60$), 7% authors will contribute 03 publications (that is, $1/3^2 \times 60$) and so on (Dutta, 2019; Maheswarappa, 1997). In this study, there are 354 co-authors of Mahalanabis. Out of which 179 co-authors (50.56%) have single papers, 72 co-authors (20.33%) have two papers, 21 co-authors (5.39%) have three papers, and 18 co-authors (5.08%) have four papers and so on. Thus, it nearly follows the Lotka’s law.

Degree of collaboration

Degree of collaboration identifies a relationship between main authors and co-authors that is called, in other words, ‘Collaboration coefficient’. It is calculated as MAP divided by TAP. It is observed from Table 7 that during 53 productive publication life, the DC had its highest value in one (1) only in 33 years. The DC value was equal to 0.5 for 1 year and greater than 0.5 for 5 years. The same was zero for 3 years that is indicating in 1981, 1987 and 1990, only single-authored papers were published by the author. Over all, DC value is 0.96. Figure 3 shows the graphical representation of variation of degree of collaboration by years.

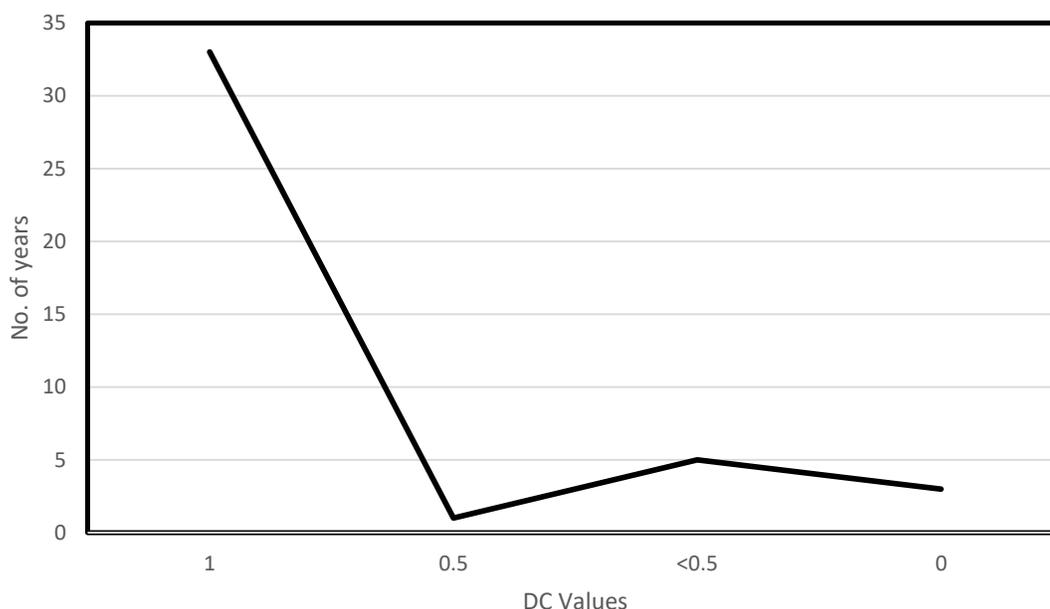
Communication channels

Table 8 shows the ranked list of communication channels of Mahalanabis’s publications. He has used 81 communication channels wherein his papers were placed.

Table 7. Year wise variation of degree of collaboration.

DC values	Years	For no. of years
1	'70, '72 to '79, '82, '86, '88, '89, '92 to '95, '97 to '02, '04 to '10, '12, '14, '22	33
0.5	'80	01
<0.5	'83, '84, '91, '96, '03,	05
0	'81, '87, '90,	03

Source: National Institute of Cholera and Enteric Diseases (NICED)
<https://www.indiascienceandtechnology.gov.in/organisations/ministry-and-departments/indian-council-medical-research-icmr/national-institute-cholera-and-enteric-diseases-niced-kolkata>

**Figure 3.** Graphical representation of variation of degree of collaboration by years.

Source: National Institute of Cholera and Enteric Diseases (NICED)
<https://www.indiascienceandtechnology.gov.in/organisations/ministry-and-departments/indian-council-medical-research-icmr/national-institute-cholera-and-enteric-diseases-niced-kolkata>

He published 229 papers, 98.28% as journal articles that is, majority of his publications were serial publications, 2, 0.86% as books/ Festschrift and 2, 0.86% as conference proceedings. *Acta Paediatrica*, and *The American Journal of Clinical Nutrition* have been his most favorite journals wherein 14 each (6%) of his papers were published, followed by *Journal of Diarrhoeal Diseases Research*, and *Journal of Pediatric Gastroenterology and Nutrition* where he placed 10 each (4.29%) of his publications. He also published 9 papers (3.86%) in *Bull World Health Organ*. Table 9 also represents that Mahalanabis's publications emanated from India, Bangladesh, UK, USA, Switzerland, Netherlands, Europe, Suffolk, Croatian, Germany, Berlin, Iran, Maryland, California, Salud, Thailand, South-East Asia, etc. A largest number of papers were foreign publications and mostly emanated from UK and USA. Only 20 papers (8.58%) were national level publications that are,

published from India, and *The Indian Journal of Medical Research* was his Indian favorite journals where he placed 7 articles. It is a notable fact that one of his papers titled "Oral fluid therapy of cholera among Bangladesh refugees" has been published three times in different communication channels viz, *Johns Hopkins Med J*. 1973 Apr;132(4):197-205; *Bull World Health Organ*. 2001;79(5):473-9; and *WHO South East Asia J Public Health*. 2012 Jan-Mar;1(1):105-112.

Bradford's law

Bradford's law divides communication channels into three zones, with each zone ideally containing approximately 33% of the papers. In this study, 81 papers (34.38%) were published in the first 8 journals. The second zone is comprised of 16 communication channels (serial numbers

Table 8. Ranked list of communication channels of Dilip Mahalanabis.

Serial No.	Communication channels	Papers	%-age	Cumulative-%	FYP	LYP	Country of publication
1	Acta paediatrica	14	6.02	6.02	1993	2002	USA
2	The American Journal of Clinical Nutrition.	14	6.02	12.04	1977	2009	USA
3	Journal of Diarrhoeal Diseases Research	10	4.29	16.33	1983	1999	USA
4	Journal of Pediatric Gastroenterology and Nutrition.	10	4.29	20.62	1992	2005	USA
5	Bull World Health Organ	9	3.44	24.06	1970	2010	Switzerland
6	European Journal of Clinical Nutrition.	8	3.44	27.50	1992	2006	Europe
7	Gastroenterology	8	3.44	30.94	1995	2001	USA
8	Journal of health, population, and nutrition	8	3.44	34.38	2000	2010	Bangladesh
9	Journal of Tropical Pediatrics.	8	3.44	37.82	1995	2006	UK
10	Archives of Disease in Childhood	8	3.44	41.26	1978	1997	UK
11	Nutrition research	7	3.01	44.27	1995	2002	USA
12	The Indian Journal of Medical Research	7	3.01	47.28	1977	1976	India
13	The Journal of Nutrition.	6	2.58	49.86	1995	2000	USA
14	BMJ	5	2.15	52.01	1991	1999	UK
15	Digestive Diseases and Sciences	5	2.15	54.16	1997	2005	Switzerland
16	Acta Paediatrica Scandinavica	4	1.72		1980	1989	USA
17	Gut.	4	1.72		1978	1995	UK
18	Indian Pediatr.	4	1.72		1984	2022	India
19	Scandinavian Journal of Gastroenterology	4	1.72		1994	2000	UK
20	The British Journal of Nutrition	4	1.72		2001	2010	UK
21	Vaccine.	4	1.72	64.48	2003	2009	USA
22	Epidemiology and Infection	3	1.28		1994	2002	UK
23	FASEB Journal	3	1.28		1996	1997	USA
24	Lancet	3	1.28		1977	2005	UK
25	Pediatrics	3	1.28		1970	2008	USA
26	The Journal of Tropical Medicine and Hygiene	3	1.28	70.88	1995	1995	USA
27	Clinical infectious diseases: an official publication of the Infectious Diseases Society of America	2	0.85		1994	1997	USA
28	Drugs	2	0.85		1995	1996	UK
29	International Journal of Epidemiology	2	0.85		1992	1996	UK
30	Journal of Clinical Epidemiology	2	0.85		1998	1999	Netherlands
31	Journal of Clinical Microbiology	2	0.85		1998	1999	USA
32	Journal of Infectious Diseases	2	0.85		1970	2003	UK
33	Journal of Pediatric Gastroenterology and Nutrition	2	0.85		1998	1998	USA
34	PLoS One	2	0.85		2014	2008	USA

Table 8. Contd.

Serial No.	Communication channels	Papers	%-age	Cumulative-%	FYP	LYP	Country of publication
35	Proceedings of the First Regional Conference, IEEE Engineering in Medicine and Biology Society and 14th Conference of the Biomedical Engineering Society of India. An International Meet	2	0.85		1995	1995	USA
36	Public Health: An Official Journal the Royal Society for Public Health	2	0.85		1994	1995	UK
37	Scandinavian Journal of Infectious Diseases	2	0.85		1996	1999	UK
38	Transactions of the Royal Society of Tropical Medicine and Hygiene.	2	0.85	81.08	1994	1995	UK
39	Acta Paediatrica	1	0.44		1998	1998	USA
40	Am J Clin Nutr	1	0.44		1979	1979	USA
41	American Journal of Human Biology: the Official Journal of the Human Biology Council	1	0.44		2004	2004	USA
42	Annals of Human Biology	1	0.44		2009	2009	UK
43	Archives of Physical Medicine and Rehabilitation	1	0.44		2007	2007	USA
44	British Journal of Nutrition	1	0.44		2000	2000	UK
45	Chemotherapy	1	0.44		1998	1998	Switzerland
46	Cholera. Current Topics in Infectious Disease (Book)	1	0.44		1992	1992	Suffolk
47	Collegium antropologicum: Journal of the Croatian Anthropological Society	1	0.44		2009	2009	Croatian
48	Critical Reviews in Tropical Medicine (book/Festschrift)	1	0.44		1984	1984	USA
49	Diarrhea and Malnutrition (book/ Festschrift)	1	0.44		1983	1983	USA
50	European Journal of Gastroenterology & Hepatology	1	0.44		1996	1996	USA
51	Food and Nutrition Bulletin	1	0.44		1994	1994	USA
52	Haemophilia: the Official Journal of the World Federation of Hemophilia.	1	0.44		2004	2004	Europe
53	Hum. Ecol.	1	0.44		2006	2006	Germany
54	Indian Journal of Experimental Biology	1	0.44		1997	1997	India
55	Indian Journal of Pediatrics	1	0.44		1991	1991	India
56	Indian Journal of Preventive and Social Medicine	1	0.44		1976	1976	India
57	Infection and Immunity	1	0.44		1995	1995	USA
58	International Journal of Anthropology	1	0.44		2006	2006	Berlin
59	International Journal of Pediatrics	1	0.44		2014	2014	Iran
60	J Trop Pediatr Environ Child Health	1	0.44		1974	1974	Maryland
61	JAMA: the journal of the American Medical Association	1	0.44		2004	2004	USA
62	Johns Hopkins Med J.	1	0.44		1973	1973	USA
63	Journal of biosocial science	1	0.44		1996	1996	UK
64	Journal of Clinical Epidemiology	1	0.44		1997	1997	Netherlands
65	Journal of Food Science	1	0.44		2006	2006	Chicago
66	Journal of Life Sciences	1	0.44		2010	2010	India

Table 8. Contd.

Serial No.	Communication channels	Papers	%-age	Cumulative-%	FYP	LYP	Country of publication
67	Journal of Neonatology	1	0.44		2004	2004	India
68	Journal of Occupational Rehabilitation	1	0.44		2007	2007	Germany
69	Journal of Perinatology: Official Journal of the California Perinatal Association	1	0.44		2008	2008	California
70	Journal of the Indian Medical Association	1	0.44		2003	2003	India
71	Nature Proceeding	1	0.44		2012	2012	UK
72	Perinatology: Journal of Perinatal and Neonatal Care	1	0.44		2005	2005	India
73	Praxis	1	0.44		1999	1999	India
74	Proc Soc Exp Biol Med.	1	0.44		1975	1975	USA
75	Revista Panamericana de Salud Pública	1	0.44		1997	1997	Salud
76	The American Journal of Tropical Medicine and Hygiene	1	0.44		1993	1993	USA
77	The Journal of Pediatrics	1	0.44		2001	2001	Netherlands
78	The National Medical Journal of India	1	0.44		2002	2002	India
79	The Pediatric Infectious Disease Journal	1	0.44		1999	1999	USA
80	The Southeast Asian Journal of Tropical Medicine and Public Health	1	0.44		1998	1998	Thailand
81	WHO South East Asia J Public Health	1	0.44	100	2012	2012	South-East Asia

FYP = First Year of Publication; LYP= Last Year of publication.

Source: National Institute of Cholera and Enteric Diseases (NICED) <https://www.indiascienceandtechnology.gov.in/organisations/ministry-and-departments/indian-council-medical-research-icmr/national-institute-cholera-and-enteric-diseases-niced-kolkata>

Table 9. Ranking of publications by number of citations received.

S/N	Title of paper	Communication channels (Year)	Times cited			Ranks			Age of the paper (A) in 2023	Citation growth rate = TC/ A		
			GS	PM	RG	GS	PM	RG		GS	PM	RG
01	Case-control study of enteropathogens associated with childhood diarrhea in Dhaka	Journal of Clinical Microbiology (1999)	424	121	329	1	1	1	25	16.96	4.84	13.16
02	Oral fluid therapy of cholera among Bangladesh refugee	Johns Hopkins Medical Journal (1973)	235	31	119	2	6	5	51	4.60	0.61	2.33
		WHO South East Asia J Public Health (2012)	-	01	-	-	18	-	13	-	0.07	-
		Bull World Health Organ (2001)	-	01	-	-	18	-	23	-	0.07	-
03	Impact of zinc supplementation on intestinal permeability in Bangladeshi children with acute diarrhea and persistent diarrhea syndrome	Journal of Pediatric Gastroenterology and Nutrition (1992)	238	52	181	3	2	2	32	9.52	1.59	5.65

Table 9. Contd.

04	Successful treatment of rotavirus diarrhea in children with immunoglobulin from immunized bovine colostrum	The Pediatric Infectious Disease Journal (1999)	218	43	164	4	4	3	25	8.72	1.72	6.56
05	Randomised controlled trial of zinc supplementation in malnourished Bangladeshi children with acute diarrhoea	Archives of Disease in Childhood (1997)	193	24	136	5	8	4	27	7.15	0.89	5.03
06	Malabsorption of water miscible vitamin A in children with guardiasis and ascariasis	The American Journal of Clinical Nutrition (1979)	165	15	101	6	15	14	45	3.67	0.34	2.24
07	Maternal and socioeconomic factors and the risk of severe malnutrition in a child: A case-control study.	European Journal of Clinical Nutrition. (1994)	162	19	104	7	11	13	30	5.40	0.64	3.47
08	Hyperimmune cow colostrum reduces diarrhea due to rotavirus: a double-blind, controlled clinical trial.	Acta Paediatrica; International Journal of Pediatric (1995)	158	24	116	8	8	6	29	5.45	0.83	4.00
09	Effectiveness of zinc supplementation plus oral rehydration salts compared with oral rehydration salts alone as a treatment for acute diarrhea in a primary care setting: a cluster randomized trial.	Pediatrics (2008)	154	45	114	9	3	8	16	9.63	2.81	7.13
10	Large epidemic of cholera-like disease in Bangladesh caused by vibrio-cholerae 0139 synonym Bengal.	The Lancet (1993)	152	-	113	10	-	9	31	4.90	-	3.65
11	Partially hydrolyzed guar gum???Supplemented oral rehydration solution in the treatment of acute diarrhea in children.	Journal of Pediatric Gastroenterology and Nutrition (2002)	139	18	105	11	12	12	22	6.32	0.82	4.77
12	Assessment of vitamin a status by the deuterated-retinol-dilution technique and comparison with hepatic vitamin a concentration in Bangladeshi surgical patients.	The American Journal of Clinical Nutrition (1997)	121	21	110	12	10	10	27	4.48	0.78	4.07
13	Helicobacter pylori infection in the young in Bangladesh: prevalence, socioeconomic and nutritional aspects.	International Journal of Epidemiology (1996)	119	23	107	13	9	11	28	4.25	0.82	3.82
14	Double-blind, randomized, controlled trial of zinc or vitamin a supplementation in young children	Acta Paediatrica: International Journal of Pediatric (1999)	118	16	82	14	14	18	25	4.72	0.64	3.28

Table 9. Contd.

	with acute diarrhea.											
15	Impact of zinc supplementation on persistent diarrhoea in malnourished Bangladeshi children.	Acta Paediatrica: International Journal of Pediatric (1998)	118	14	80	14	16	19	26	4.54	0.54	3.07
16	Clinical trials of improved oral rehydration salt formulations: a review	Bulletin of the World Health Organization (1994)	116	02	78	15	17	21	30	3.86	0.67	2.60
17	Scientific rationale for a change in the composition of oral rehydration solution.	JAMA: the Journal of the American Medical Association (2004)	114	16	83	16	14	17	20	5.70	0.80	4.15
18	Impact of zinc supplementation on subsequent growth and morbidity in Bangladeshi children with acute diarrhea.	European Journal of Clinical Nutrition (1999)	113	15	88	17	15	15	25	4.52	0.60	3.52
19	Post defecation handwashing in Bangladesh: practice and efficiency perspectives.	Public Health (1995)	112	-	82	18	-	18	29	3.86	-	2.83
20	A randomized, placebo-controlled trial of the bivalent killed, whole-cell, oral cholera vaccine in adults and children in a cholera endemic area in Kolkata, India.	PloS one (2008)	110	37	115	19	5	7	16	6.88	2.31	7.19
21	Oral rehydration in infantile diarrhoea. controlled trial of a low sodium glucose electrolyte solution.	Archives of Disease in Childhood (1978)	110	15	70	19	15	22	46	2.39	0.32	1.52
22	In search of a super Solution: controlled trial of glycine-glucose oral rehydration solution in infantile diarrhoea.	Acta Paediatrica Scandinavica. (1984)	103	17	84	20	13	16	40	2.58	0.43	2.1
23	Costs of illness due to typhoid fever in an Indian urban slum community: implications for vaccination policy.	Journal of Health, Population, and Nutrition (2004)	100	29	79	21	7	20	20	5.00	1.45	3.95

Source: Data collected from Google scholar, Research gate.net and PubMed.

9 to 24), which account for 79 papers (33.94%), including 2 conference proceedings and 2 Festschrifts. The third zone consists of 73 papers (31.68%) published in 57 communication channels. As per Badford's Law (Hertzal, 1985;

Maheswarappa, 1997), the ratio of numbers of communication channels in the first and succeeding zones should be as 1: n : n² . Here, the ratio is 8: 16: 57 or 1:2:7. Hence, the data set follows Badford's Law.

Citation received (cited by) and citation growth rate

From available Abstracting and indexing online free databases such as Google Scholar (GS),

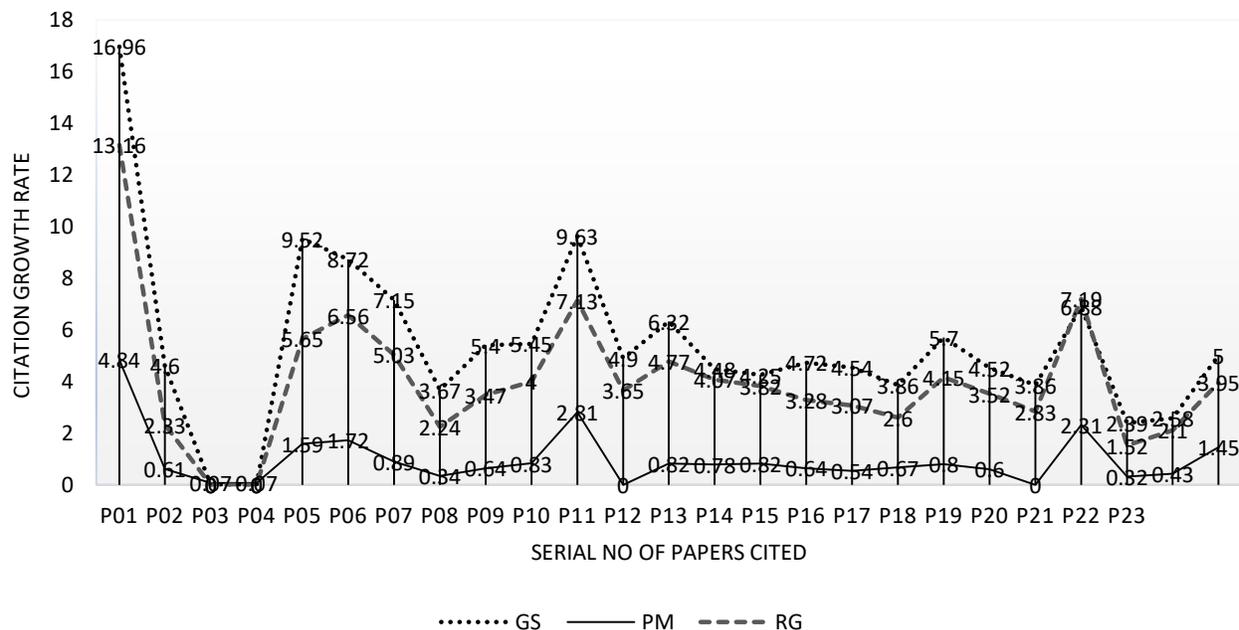


Figure 4. Citation growth rate of papers in GS, PM, RG.

PubMed (PM) and ResearchGate (RG) (Google Scholar (n.d; PubMed (n.d), a ranking list of top 23 articles with name of communications channels and publication year for citation received has been shown in Table 9. It shows that the article “*Case-control study of enteropathogens associated with childhood diarrhea in Dhaka*” ranked first at par Google Scholar (424 citations), PubMed (121 citations), and Research Gate (329 citations). The Citation Growth Rate (= *Total Citation received* divided by *age of the paper in 2023*) of the 23 papers are also listed there. As per first rank, Citation Growth Rates (CGR) is 16.96, 4.84 and 13.16 respectively. CGR in Google Scholar is high that is, 16.96 followed by 13.16 in Research Gate. Figure 4 shows the citation growth rate of papers in GS, PM, RG.

Conclusion

This study is a tribute to the renowned Bengalee pediatrician, Dr. Dilip Mahalanabis, highlighting major aspects of his life and research works. As a member of WHO’s Diarrheal Disease Control Programme, he engaged wholeheartedly and for this purpose, he travelled different countries over the world to prove the efficacy of the use of the “salt-sugar-water” mixture and promote research in laboratories throughout his 53 years of service period and retired life. Finally, he has proved and fulfilled the objectives of WHO’s health programme and Oral Rehydration Solution (ORS) gained popularity and globally acceptance and was later praised as one of the important and useful discovery

of the 20th century in the field of medical research (Mayor, 2023). Our country, as well as the whole world, will remember the medical scientist for his epoch-making discovery 'ORS' (a salt-sugar-water mixture, that is, oral saline). His death is a great loss in the field of medical research and marks the end of an era. His discovery, ORS, will remain the mainstay of treatment for diarrheal diseases in children and others. The conclusion may be summed up with the words of Gautama Buddha: 'Being born is a matter of fate; death is a matter of time, but what truly matters is the work that remains in people's minds and hearts even after death (Goutam, n.d).

CONFLICT OF INTERESTS

The author declares that there is no conflict of interest.

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