

VIGYAN PRASAR

DREAM

2047

SEPTEMBER 2022 / Vol. 25 / No. 9 / ₹ 20

IMPORTANCE
OF LEARNING
SCIENCE IN THE
MOTHER TONGUE

AGE OF
ULTRASONICS

VERA RUBIN
AND THE MYSTERY
OF HIDDEN
DARK MATTER



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Published by Dr Nakul Parashar on behalf of Vigyan Prasar, A-50, Institutional Area, Sector-62, Noida-201 309, U.P. India.

Cover Design & Illustrations By: BIPRO KUMAR SEN

MY WORD

NAKUL PARASHAR

SCoPE: Humongous Opportunities**AS WE ENTER**

the Amrit Kaal, the period from now till 2047, we are proud to have more than 1055 Universities and 161 Institutes of National Importance. This means that we produce more than a million graduates and post-graduates in different disciplines of science & technology every year. This means that a sizeable student population from this number pursues research leading to a PhD degree. Yet, from the total population standpoint, this number would need to proliferate to meet the target of converting the country into a developed nation before we celebrate the 100th year of independence. So, how do we do it?

The answer, of course, is creating mass awareness about science & technology and setting up actions as our bit to make our nation a developed one before 2047. We know there are umpteen ways to generate mass awareness about our scientific and technological prowess. Also, we know how everyone can come forward and contribute their part to it. We can do that by enhancing & innovating the means of science & technology-related mass communication (print-electronic-social-digital media). We can do that by hands-on demonstration & focused workshops on skill-building about SCoPE (science & technology communication popularisation and its extension). We can promote & support agencies & individuals involved in the propagation of S&T communication & popularisation. We can bring S&T research & development closer to society by evolving a trained & structured interface as a fully-grown interdisciplinary domain of S&T and Mass Communication. The list of actionable items is, thus, long

and would continue to count. This indicates that there is enormous potential for SCoPE. Isn't it?

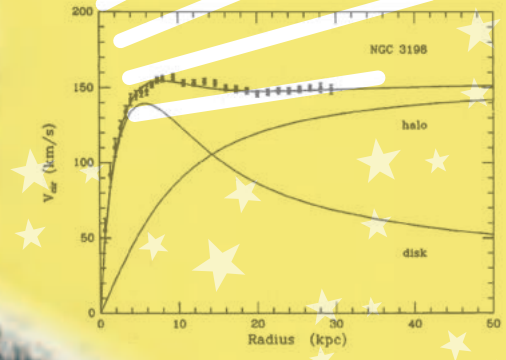
Of course, the ground for SCoPE to grow is far more fertile now than earlier. Access to our S&T prowess is far easier than it was earlier. The amount of S&T-related data is getting accumulated rapidly as a large number of our universities and institutes of national importance continue to churn newer results daily. Interestingly, most of the research we carry out in our places of academic excellence has so far borne results that catalysed plausible and sustainable start-ups. Thanks to a relevant programme like AWSAR (Augmenting Writing Skills for Articulating Research) that is executed by Vigyan Prasar, where young researchers are trained and awarded for their writeups about what they do in their labs while pursuing their PhD degrees and Post-doctoral work.

In turn, to ensure that this endeavour of mass awareness does not remain a moment of triumph but a way of life for every citizen of the country, these nationwide drives would produce a continuous boost to the nation's economy through new business & job opportunities. In its journey so far, Vigyan Prasar has relentlessly worked and continues to train resources and equip them with all possible knowledge to meet the nation's SCoPE-related requirements. A critical need for all of us to look at it with a focused approach to create many more such organisations and a vast number of trained resources. Hence proved!

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COVER STORY

K E BALAGOPALAN



VERA RUBIN AND THE MYSTERY OF HIDDEN DARK MATTER

Vera Florence Cooper Rubin (23 July 1928-25 December 2016) was more an observer than an astronomer. She was not a theorist, but was the first to drag the entire astronomy into the quest for the elusive 'Dark Matter'. She was indeed the first woman who boldly encountered the challenge of gender discrimination in the field of education, especially in astronomy.

Rubin was a native of Washington. From the very childhood itself, she started observing the sky. Her father assembled telescope for her with a lens and a cardboard tube. The motion of the stars as visible through the window of her north-facing bedroom attracted her much. She was around the age of 10 and she immersed herself in stargazing at midnight instead of sleeping. During school days her great wish was to possess a reflecting telescope with mirrors and refracting telescope with lenses. The seasonal change of the stars amazed her.

HIGHER EDUCATION

Rubin did her graduate studies at Cornell University and Georgetown University in USA. Her science teacher advised her to avoid a career in science and become an artist. Turning a deaf ear to her teacher's advice, she graduated in astronomy to be the only graduate in the subject during 1948. At that time women had only limited scope for graduating in astronomy. She attempted to enroll in a graduate programme at Princeton but was barred due to her gender. At that time Princeton did not accept women for graduation in astronomy. She secured her master's degree in 1951.

When Rubin began her doctoral studies at Georgetown University, she came into contact with George Gamow who became her eventual doctoral advisor. Throughout her course of graduation, she experienced discouraging sexism. She was not permitted even to meet with her advisor in his office because women were not allowed in that area of the University. Her husband had to drop her at the residence of George Gamow.

While she was researching on 'the distance and velocity of the galaxies' in the light of the 'Hubble flow', which describes the motion of galaxies due solely to the expansion of Universe, she found certain discrepancies. This discrepancy was later termed as 'galaxy rotation problem'. When the mass profiles of the galaxies are calculated from the distribution of stars in spirals at stellar disks, they do not match with the masses derived from the observed rotation curves and the theoretical prediction. It seemed to violate the law of gravity as well. The calculation of mass at galactic center could not be done with the help of 'mass-to light ratio' as carried out in star-centered planetary systems.

The discrepancy detected by Rubin pointed to a slight deviation from 'Kepler's third law' that orbital velocities of planets should decline with distance from the galactic center. Of course, the orbital velocities of planets in the solar system decline with distance from Sun. But stars situated far away revolve around their galactic center at equal or even at increased speed as observed. Initially, this discrepancy was explained by astronomers as an 'apparent' rather than 'actual' anisotropy in the expansion phase of Universe and was neglected.

She found that some galaxies appeared to be

clustering. This was against the homogeneity principle. Her observation was ignored on the pretext that it was only a local problem and that on very large scales, Universe would adopt a uniform distribution. In Hubble's view, the galaxy clusters may be mere accidents of nature, or perhaps some sort of cosmic optical illusion arising from multiple galaxies visible along our line of sight. Because this was Hubble's view, a generation of astronomers followed it.

Astronomer Edwin Hubble suffered a major heart attack at the age of sixty during the summer of 1949. Allan Rex Sandage, his student had to shoulder the responsibility then onwards. After Hubble's death, Sandage and his collaborators derived a different value for Hubble constant, which was again changed in 1980. Despite its name, the Hubble constant is not a constant. Its value has changed over time.

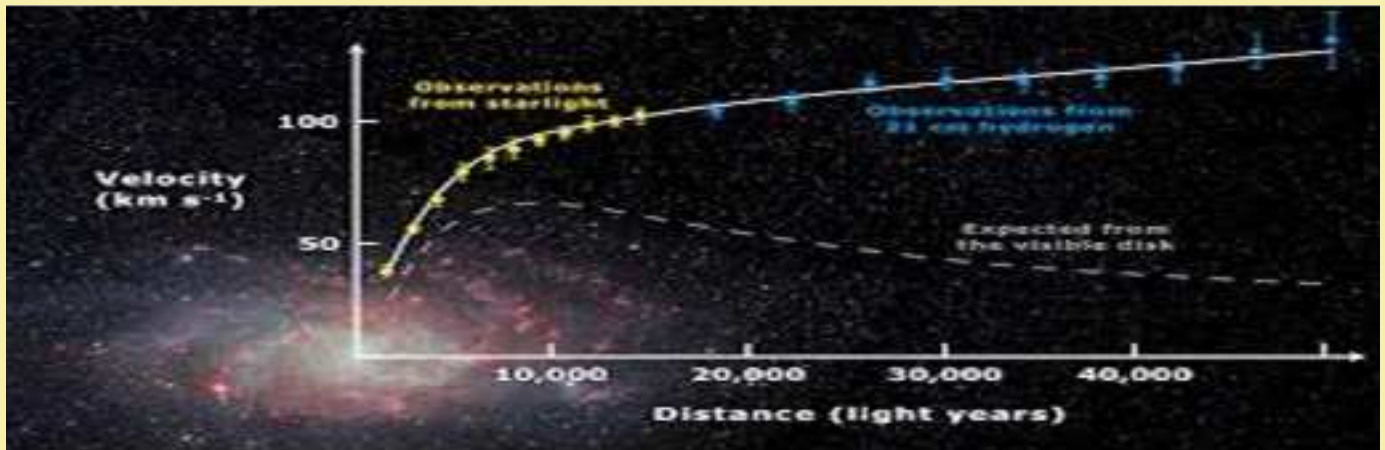
THE RUBIN-FORD EFFECT

In 1965, she met her long-term collaborator and instrumentalist W. Kent Ford. Because she had young children, she had to work from home all the time. At the Carnegie institution, she could start her work relating to the controversial topic regarding galaxy clusters at Palomar observatory which was devoid of adequate facilities for women. She created her own women's rest room and sidestepping all the deterrent factors, she became the first female astronomer to observe there.

W. Kent Ford, an industrialist, had built a tube spectrograph, a variation on the standard instrument to record the electromagnetic spectrum from a source of light. Instead of photographing the light from a distant source, he managed to convert its faint photons into a fountain of electrons and then sprayed it onto a phosphorescent screen which, in turn, gave off a vivid glow with all the clarity of a normal camera.

The Rubin-Ford effect mainly described the apparent rather than actual 'anisotropy' in the expansion of the Universe. They observed that the farther the planet from Sun, the slower was the orbit. A planet 4 times as far as another would be moving with half the velocity of the latter. At 9 times the distance the velocity would be one-third. This is, however, not the case with the stars in the galaxy. The outermost stars and gas clouds





seemed to be revolving around the centre of the galaxy at the same rate as the innermost stars and the gas.

In their 1973 paper, Rubin produced her data. She held that the galaxies are not in recessional motions although some peculiarity is certainly there. The galaxy clusters were developing towards one part of the sky. The discrepancy in her calculations as well as in the observed rotation curves with the law of gravity was really a problem. Rubin thought of this and at last her brain wave did find a solution for it by introducing 'dark matter'. She concluded that some invisible matter almost 5 times in quantity than the visible matter is exerting a pulling force jointly with the gravity of baryonic matter against the repulsion of dark energy.

From the very beginning, the 'Rubin-Ford effect' was subjected to virulent arguments in the scientific community, including cosmologists. Prominent astronomers even begged her to regress from the field and drop her line of research so as not to spoil her career. Suffering a lot of mental agony, she strived hard to push it to the end and at last published her work in 1976 as two papers, providing the complete set of data as established in Rubin-Ford effect as real.

The discovery of the Dutch-American astronomer Maarten Schmidt about quasars (Quasi-stellar radio sources), which are point-like extraordinarily bright sources of radio signals coming from the farthest depths of space, provided breathtaking new evidence for astronomers to realise that Universe visible in radio wavelengths is not the Universe we see with our eyes. It was also discovered that there are some counter rotations. Some gas and stars moved in the opposite direction to the rotation of rest of the galaxy. Prevailing theory was that all of the material of galaxy moved in the same direction. Wishing to avoid controversy, Rubin avoided quasars and galactic motions and concentrated on the study of galactic rotation, counter rotation and its outer reaches. She did not like everyone challenging her on every point of her novel assumptions.

She was invited to attend a Yale conference shortly after the publication of the papers on Rubin-Ford effect. Till then, she was treated only as an observer. While walking through the entrance of the venue, she noticed a huge banner

'ASTRONOMERS' hanging above it. She thought wryly. "Now, I am an astronomer."

THE HUMORIST IN VERA RUBIN

Stephen Hawking had once opined that a number of prizes had been awarded simply to be held in Princeton, USA as part of the University's 250th anniversary celebrations. Participating in "Critical dialogues in Cosmology", Vera Rubin summarized the situation with a joke. "There was a wise rabbi, who was trying to mediate a marital dispute. When the husband complained about his wife, the rabbi said, "You are right." The wife complained about her husband in turn. "You are right." The rabbi said. Then the rabbi's own wife, eavesdropping behind a curtain all the time, appeared and questioned rabbi: "How can you tell them both they are right?" The wise rabbi replied passively. "You're right too."

ROTATING UNIVERSE

In the Universe, all galaxies are in motion. Vera Rubin says, "Within a galaxy, everything moves. Every two minutes, Earth has moved 2,500 miles (4,023.36 km) as it orbits Sun; Sun has moved 20,000 miles (32,186.88 km) as it orbits the distant center of our galaxy. In a 70-year old human lifespan, Sun moves 300,000,000,000 miles (482,803,200,000 km). Yet this vast path is only a tiny arc of a single orbit; it takes 200,000,000 years for Sun to revolve once around the galaxy." She had tried to show with her own master thesis that Earth is rotating, the solar system is rotating, and the galaxy is rotating. If so, "Why not the Universe?" she wondered.

Jim Peebles, the 2019 Nobel Laureate, with his CDC 3600 computer, loaded a film projector to run the majestic frames of radio photographs. The Universe swirled to life. Galaxies moved outwards as per the 'Hubble's flow'. But at times they slowed moving under the influence of their mutual gravitational attractions and they continued to slow, then followed the 'Hubble's flow' and moved with expansion and again began to fall back. Smaller galaxies clumped with nearest larger galaxies and those clumps clumped with other clumps. The more the galaxies clumped, the more those clustered.

GAMOW, HER EVENTUAL DOCTORAL ADVISOR

Vera Rubin had high regards for the formidable George Gamow, her doctoral advisor. She was of opinion that Gamow was a special type of genius. One can only watch him. No one's mind can work in that way. He snoozed during lectures and asked redundant questions. At the same time, he answered questions that nobody can answer. His personal failure, Rubin says, "When he spoke, you listened."

When Arno Penzias and Robert Wilson measured the Cosmic Microwave Background Radiation correctly as 3 Kelvin as per the excellent prediction of George Gamow and his student Ralph Alpher, Jim Peebles, the 2019 Nobel Prize winner submitted his initial paper on the CMBR temperature to *Physical reviews*, through 'Dick's Bird Group'. It was immediately rejected as, by mistake, it had duplicated some earlier calculations by Alpher, Herman, Gamow, and others. Gamow sent an angry note to Penzias listing citations of his early work. Conclusion was a severe reprimand against Dick: "Thus, you see, the world did not start with Almighty Dick".

THE LATE VINDICATION

After long twenty years, Rubin's early work was vindicated. After that unforgiving AAS meeting, she could project herself splendidly. According to quantum mechanics also, empty space can generate virtual particles depicting Universe as a 'quantum pop'. Her article, "Rotating Universe" published in *Nature* during 1973 had raised a tornado in cosmology and anticipated the existence of dark matter.

'Dark matter' is called dark because it does not interact with the electromagnetic field, which means it does not absorb, reflect or emit electromagnetic radiation and is therefore difficult to detect. Most dark matter is thought to be non-baryonic in nature. Although we still don't know what dark matter is, WIMPs (Weakly Interacting Massive Particles), MACHOS (Massive and Compact Halo Objects), Axions, and Neutrinos are 'dark matter' candidates. As per latest measurements, Universe is filled with 72.74 % of Dark energy, 22.7% of Dark matter and 4.56 % of baryonic matter. May it be as Vera Rubin joked, dark matter was "cold planets, dead stars, bricks or baseball bats".

TWO TYPES OF DARK MATTER -THE HOT AND THE COLD

If hot dark matter exists, particles moving at relativistic velocities would have smeared the primordial ripples to large volumes, like a downpour on sidewalk chalk. Gathering around those vast swaths of Universe, large structures of matter would

have had formed first. These vast lumps of matter would have had broken up into the specks we see today as galaxies. The Universe would have had a top-down, complex-to-simple, a macro-to-microhistory.

If cold dark matter exists, particles moving at a small fraction of the speed of light would have sprinkled the primordial ripples much subtly and affected the evolution more slowly. Structures in that Universe would have started as specks of galaxies and worked its way up to larger and larger structures. Universe would then have had a bottom-up, simple-to-complex, micro-to-macro history.

THE STRUGGLE ENDED

In a field like astronomy, where there was utter male domination, Rubin could accept the challenge of gaining credibility by her own motivation. She had faced many discouraging comments throughout her life but she stuck to the choice of her study, of course supported by her husband and colleagues. She had encouraged girls as far as she could throughout her career so that they should never experience such a bias in the educational field like her. An observatory in her name has been started by National Science federation "Vera C Rubin observatory" in Chile. It is under construction, now.

SHE WROTE:

- 1) There is no problem in science that can be solved by a man and that cannot be solved by a woman.
- 2) Worldwide, half of all brains are in women.
- 3) We all need permission to do science but for reasons that are deeply ingrained in history, this permission is more often given to men than to women.

Vera Rubin was unfortunately skipped while considering for Nobel Prize like Jocelyn Bell Brunel who built the telescope and spotted the first signal of 'pulsars'. Only three women were lucky in this regard; Marie Curie in 1903 for the 'radioactivity', Maria Goeppert Mayer for the 'atomic structure' in 1986, and Donna Strickland in 2018 for 'CPA technology' in laser.

Rubin had entered the hall for submission of her famous paper with one child in her hand and the other in the pram. All the four of Vera Rubin's children earned PhDs in the field of science. They say that their mother's passion had motivated them. She would admit that she wasn't 'smart enough' to know why the Universe was in the way it was. "I used to think that if I had to design a woman's plumbing, I could have done a better job", she said."

Rubin passed away on 25 December 2016 at the age of 88.



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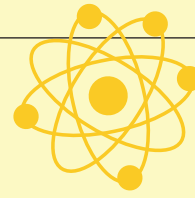


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Importance of learning science in the mother tongue

It is well-known that higher studies in science cannot be done in any Indian languages, and we in India need to embrace English for studying science may be in the plus two levels or even earlier. And for studying science at a higher level, we are compelled to give up the use of our mother tongue, which may be one of the major Indian languages. So what is the point in arguing in favour of teaching science in the mother tongue? In fact, this leads to a stronger argument that science may be taught only in English right from the beginning since that has to take up sooner or later. Let me admit; there are definitely some valid points in these arguments. But there are issues that we sometimes miss out. The first one of these issues is possibly more important, and I would like to discuss it in more detail, and then I shall take up another important point. But at the outset, please allow me to begin with a caveat.

Let us not confine ourselves to the conventional definition of science that makes up for the contents of the

science textbooks and are taught in the classrooms. But let us look at the world around us and the questions that pop up in the mind of a child demanding scientific explanations when she is getting to know the world around her. A child moves around her surrounding, which is likely to differ from child to child. She may be growing up in a village where she comes across lots of trees, water bodies, colourful birds, insects, and small animals, houses with different constructions, buses plying along the road that has passed through her village, and so on. Or if a child is growing up in an urban set up, her observations do have something in common with her counterpart in a village but she can also come across with different contraptions like an elevator, a multistoried building, a fast-moving vehicle along with the trees, birds, and small animals.

The science begins with the observations and the process of raising questions based on these observations. Then we, the adults, help a child link up the observations with consistent

explanations and predict possible scenarios that may evolve as a logical consequence. For example, if we convince a child that trees need sunlight to grow up, then one should plan a simple experiment at home to show that it is the case. This, of course, is not at all an easy task. But for the communications and scientific explanations related to the observations, if done in the mother tongue, an artificial barrier between the observations, a child's thought process and the articulations of the adults may be removed. All these may be put together sequentially using the string of the mother tongue, the language used for explanations.

Can any grown-up person like us imagine the number of questions that come up in a child's mind through these observations? It is difficult to gauge as the children are very critical observers and valid questions do crop up in their minds. Often their eyes are half a meter lower than that ours, and in the process, they can pick up so many things that we cannot. They are unlike adults who have

taken for granted so many happenings around them as something 'normal' without any scope for raising further questions. Adults do not think why the different leaves from various trees have different shapes and sizes, why some trees are long while some others are not, why some birds have bright colours, why some birds 'sing' sweet and why our domestic electricity supply is ac and not a dc etc. The list tends to be longer, and unfortunately, most adults do not pay much attention to taking these questions from the curious children head-on. And possibly, as a result, our children cannot acquire the courage to raise questions in the classrooms, which is a primary condition for learning science. We need to empower them.

Naturally, as guardians, we cannot provide ready replies to most of these queries. But once again, we now have some great devices in our hands or on or on our table or in our bag to look for these answers. We have to devote that time to the children. We have to look for a good reply to her query and shall have to try to present that to them. Once again, mother tongue becomes very handy in this regard though we may gather these replies in some other languages, mostly in English. She should not only be provided with the replies, but that has to be done in a way that keeps her encouraged to raise further questions.

This is, of course, a very important a serious duty of the seniors at home, but once again, I do agree that it is not an easy task. A child picks up her mother tongue that is being used at home. She may not have a great vocabulary, and sometimes her framing of questions may lack clarity. But with the mother tongue at her disposal to express herself, this can quickly improve. Things do not stop here. Once the child has got a consistent explanation for an observation, she is likely to share it with her friends and classmates. That helps her to take a different role, and with the mother tongue used for the purpose, she can achieve this in a faster and better way. We need to know the technical terms in the mother tongue to satisfy these children. Once again, we can turn to the

device where one all-powerful translator 'resides'. The performances of the translators are not beyond criticism, yet it is really helpful. So we can be useful to the children. Once a child gets consistent replies to her first set of questions based on the observations of her surroundings, she can take more interest in the act. Once these explanations are made to them in their mother tongue and the children are encouraged to raise more questions, the learning of science begins, albeit in an informal way. And when a student gets to know about science and the situations that science explains, she feels that science is a part of everyday life. And it is not an abstract set of theories or experiments and is very much rooted in life. Formal learning of science becomes easier.

We should not forget that a child raises questions starting mostly with 'whys' and 'hows', and as adult people, we know the answers are not always that straightforward. Deeper concepts may prove to be necessary to explain apparently simple observations of the children. That way, we also need to equip ourselves. The guardians may think of building up a suitable online forum where questions from the children may be put up to receive replies suitable for them. I have taken more words to talk about a point that I

considered not only important but also of general nature. Now let me underline the second but no less important issue involving the learning of science in the mother tongue. And I shall begin this by humbly putting up a question before you. In the section of students that go for further education after crossing the 10th standard, what percentage of them actually pursue the next level of studies with science? Or, for that matter, to what extent do their studies demand the knowledge of science? I do not have an exact answer, but I can assure you that this section is below twenty percent. Among the rest, say 80%, a large section took a decision that they would not pursue science from plus two and, if possible, from class 9. As a result, teaching a subject for which a large number of students have developed some detachment using English actually becomes even more futile.

A society or a government wants its members or citizens to develop a scientific outlook and as the end users of a large number of technologies that have entered in our everyday life they should be able to appreciate the role of S&T. A section of these citizens when they turn into guardians do feel the importance of providing training in science to their children. If this section is taught science in their mother tongue, they could possibly use it in a better way for their children. This large section did not pursue science because of so many reasons, but as guardians, they cannot deny the role of science for their wards. Science possibly did not fit into their way of thinking, but most of these people want their children to know science. And if they could have their training in their mother tongue, they could possibly play a bigger role in imparting not only the knowledge of science to their children but can initiate a process that could bring them closer to science, from where they drifted away.

Science begins with the observations and the process of raising questions based on these observations.

It is necessary to help a child link up the observations with consistent explanations and predict possible scenarios.

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AGE OF ULTRASONICS

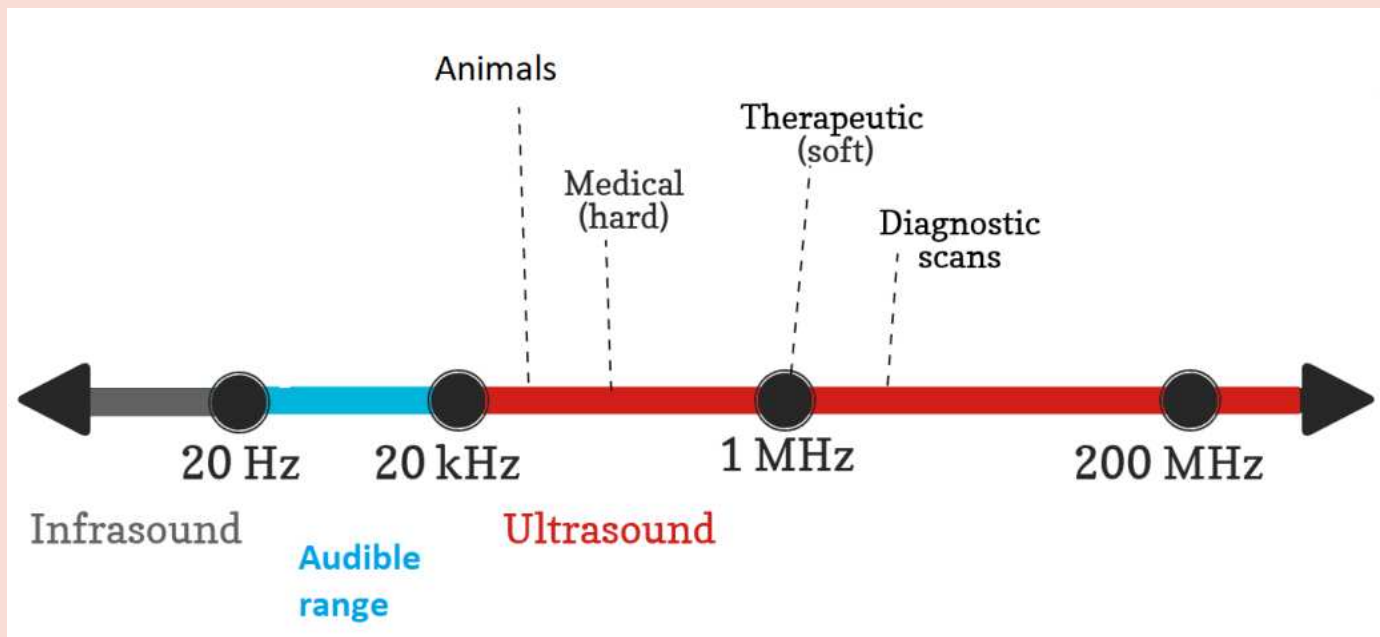
Acoustic or sound energy is categorized as clean energy. Sound production does not entail harmful effects on the ecosystem, as long as it is not a byproduct of a nuclear explosion. The frequency range of human hearing is between 20 Hz and 20 kHz. Ultrasonic waves are sound waves having frequencies higher than 20 kHz (figure 1). Nowadays, the technology has developed so that it is possible to produce ultrasonic waves of frequencies as high as 0.5 MHz.

Sound Navigation and Ranging, is a case in point. Ships at sea and submarines use SONAR to determine obstacles in their path.

Properties of Ultrasonic waves

- a.** Ultrasonic waves are longitudinal waves that produce alternate compressions and rarefactions. They have a frequency greater than the audible range for humans (>20 kHz).
- b.** They have smaller wavelengths, resulting in high penetrating power.

- f.** They undergo reflection, refraction, and absorption.
- g.** They produce heating effects in certain materials.
- h.** They are highly energetic.
- i.** Their propagation speed in a medium depends on their frequency. The more the frequency, the more the speed.
- j.** They show insignificant diffraction due to their small wavelength. Hence, they can be transmitted over long distances without substantial energy loss.
- k.** Intense ultrasonic waves can disrupt



The sound spectrum

The earliest applications of ultrasonics were based on the discovery that mammals like bats, whales, and dolphins use these waves to gauge their environment. They emit a series of short, high-frequency sounds, and from the returning echo, they are able to detect obstacles or prey in their vicinity. This was termed 'echolocation'. Echo sounder or SONAR, an acronym for

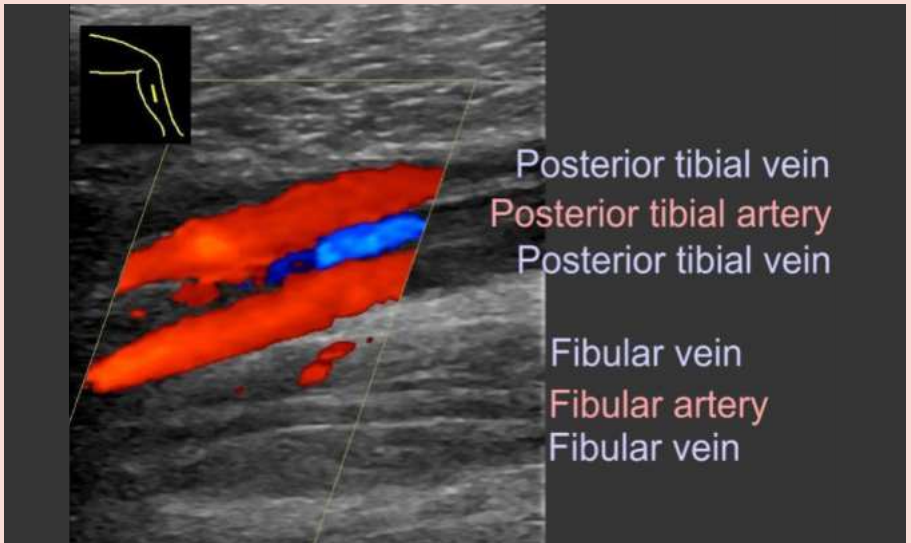
- c.** As ultrasonic waves are sound waves, they require a material medium for propagation. They are not able to travel through a vacuum.
- d.** Ultrasonic waves travel at the speed of sound in a medium. The more the density of a medium, the more the velocity of these waves.
- e.** In a homogeneous medium, they travel at a constant velocity.

liquids by causing bubbles to be formed. This is termed 'cavitation.' Innovations in technology have reached new heights, leading to sophisticated applications of ultrasonic waves. This article will review a few unique applications of this range of sound waves.

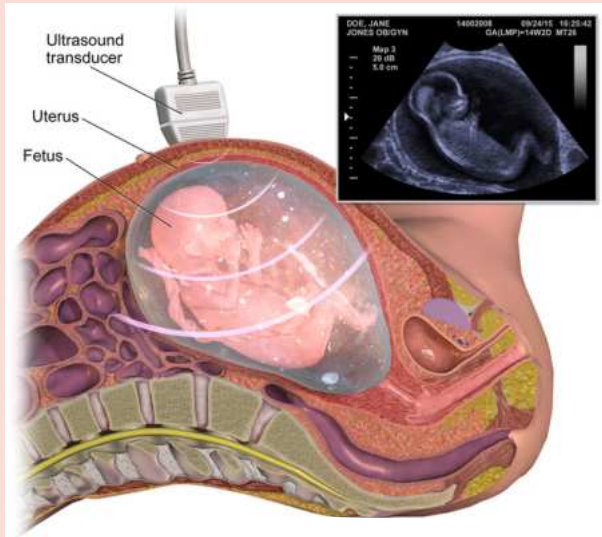
1. Ultrasound in the medical field— there are many applications of ultrasonic

waves in the medical field. These waves are used not only for detecting disorders in the body but also have therapeutic applications.

Ultrasound imaging is a technique widely used in the medical field. It is similar to echolocation. Sound waves are beamed inside the body, and their reverberation creates a digital image of the interior. This facilitates detecting internal injuries, which are otherwise invisible. The foetus inside the mother's womb can be monitored periodically to estimate its well-being and proper progress (figure 2). Sex determination of the foetus is also possible using ultrasound imaging, universally known as sonography.



Colour Doppler Image



Foetal ultrasound

Colour Doppler is another advanced imaging technique, which is a painless way to check the blood flow in arteries and veins in the body. When the sound of a given frequency is transmitted towards a stationary object and is reflected back, the frequency of the reflected waves is the same as that of the transmitted waves. But if the object is moving, a change in frequency is observed. This change in frequency is known as the Doppler shift. When the object moves toward the transmitter, the reflected waves will have a higher frequency, termed a positive Doppler shift.

In contrast, if the object moves away from the transmitter, the reflected

waves will have a lower frequency, termed a negative Doppler shift. Thus, measuring the frequency of the reflected sound waves helps establish whether the object is moving towards or away from the source. The positive Doppler shift is depicted as red, whereas the negative Doppler shift is depicted as blue in the imaging instrument. This is the basis of colour Doppler imaging (figure 3). The ultrasonic waves are radiated by a suitable

source to travel through the fluids in the body, and the reflected waves are observed and analyzed. The colour of reflected waves reveals the direction of flow, and the time interval between the emitted and reflected waves is used to ascertain the velocity of the fluid analyzed. This permits imaging of the blood flow in vessels in real-time, without the use of radioactive tracers.

Ultrasound Computed Tomography is a groundbreaking technique developed for the detection of cancerous growth and tumors in the body.

Echocardiography is a procedure that employs pulses of ultrasonic waves to image the performance of the heart on

the computer and reveal imperfections therein. This technique is painless and non-intrusive and is specifically useful for detecting congenital heart syndromes.

Lithotripsy is a medical procedure that involves cavitation generated by tremendously high amplitude shock waves to shatter kidney stones.

2. Flaw Detector—just as ultrasonic waves are able to see inside the human body, they can be used to perceive imperfections in materials. This method is non-destructive testing, which is employed in all types of manufacturing processes. The ultrasonic waves of suitable frequency are created by piezoelectric crystals like quartz or tourmaline. These waves are then transmitted through the specimen to be examined. They are reflected from the opposite end and then transformed into electric signals. The reflected and transmitted pulses are compared. Any change implies flaws like holes or cracks in the material assessed. A study of the reflected pulse reveals the position of the deformity.

Fatigue sets in metallic structures like beams, shafts, and rods after prolonged use. We frequently hear news about old buildings and bridges collapsing, the reason being wear and tear due to changes in load and other factors like corrosion affecting the metallic parts. Micro cavities are formed, and

defects like dislocations take place. These are subtle changes that are difficult to detect using conventional flaw detectors. Ultrasonics enable the detection of these minute defects. There are special instruments that produce ultrasonic waves in pulsed form, which are passed through the specimen. The rates of propagation and attenuation are measured, thereby facilitating the detection of flaws in materials (figure 4).

The ultrasonic non-destructive testing method is preferred over the X-ray detection method, as it is economical and more dependable. The X-rays used for such testing require exceptionally high voltages. Another shortcoming of the X-ray method is that the equipment is quite complicated and cumbersome compared to ultrasonic equipment.

3. Depth assessment of water bodies—the depth of sea or lakes at any point can be ascertained by the echolocation method using ultrasonic waves. The instrument used is a fathometer or echometer (figure 5).



Fathometer

A piezoelectric crystal is used as a transmitter, and another one is used as a receiver of ultrasonic waves. Generally, a pulse of 40 kHz frequency is sent out by the transmitter. The receiving crystal is also equipped with an amplifier to amplify the received signal and a time measuring device to calculate the time interval between transmitted and received pulses (figure 6). A Cathode

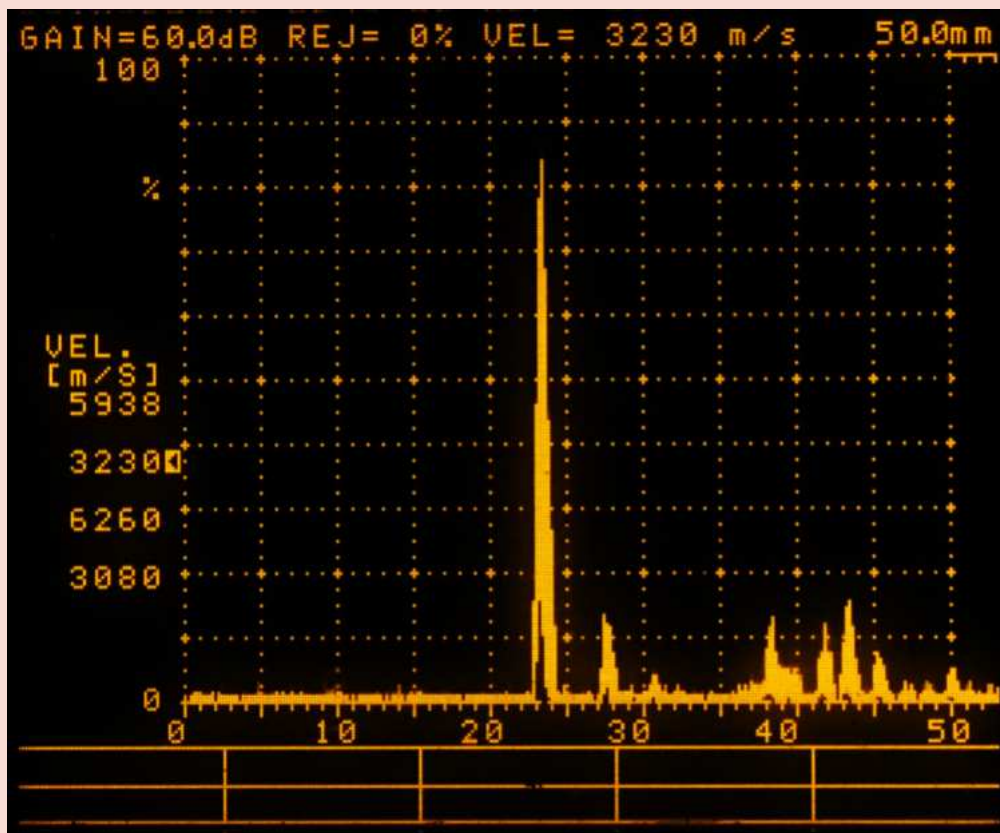
Ray Oscilloscope (CRO) can also be used to determine the exact time interval visually. The distance can be determined by the simple formula as shown below:

Distance = velocity of sound waves in water x time
The velocity of sound waves in water is approximately 1.480 km/s.

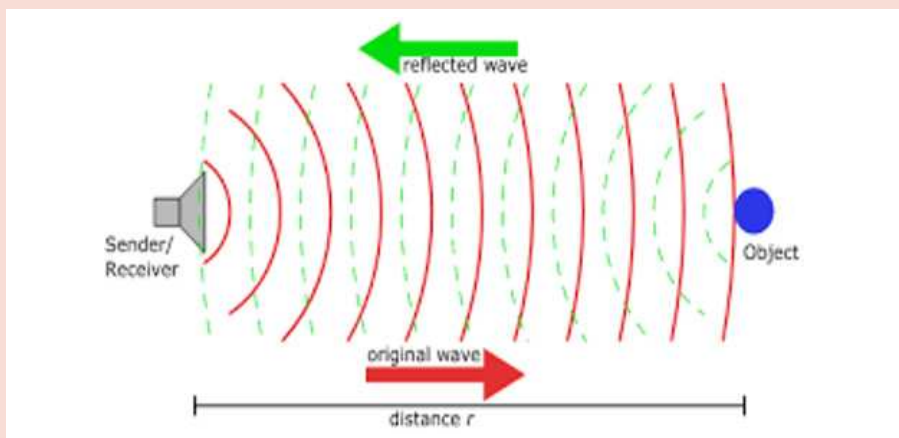
The same equipment can be utilized to determine the position of ships at sea or the location of submarines underwater. This equipment is also helpful in detecting the presence of icebergs in the ocean. Thus, disasters like the Titanic can be avoided by using such contemporary equipment.

4. Means of communication—in vast oceans, it is not possible to install mobile towers for cellphone communications. Ultrasonics provides a means of communication between ships and submarines.

A piezoelectric crystal is shaped into a plate and generates high-frequency sound waves in the form of a beam, which can be directed in the desired direction. The thickness of the beam is inversely proportional to the radius of the plate. Hence, as the radius is increased, the beam becomes narrower. This enables the beam to be focused at a small angle, about 50. This equipment has the distinct advantage of low power consumption, which is a necessity in ships, where power is not generated, only used. These signals can either be sent by Morse code or by telephony to a distance of about 15 km from the transmitter. Another vessel at sea within a radius of 15 km, if equipped with a suitable receiver, can receive the signal, and hence communication can be established between the two ships.



Flaw detection using ultrasonics



Determining distance of an object using ultrasonic waves

5. Assessment and enhancement of Food quality

–the quality and shelf life of food products can be enhanced by radiation methods. But although safe, people are apprehensive about consuming food processed in any way by nuclear radiation. Ultrasonic waves provide a non-radiative, non-destructive method of quality testing, processing, and improving the nutritional value of various food products. These methods have the added advantage of being inexpensive, low power consumption, less complex, environment friendly, and can be used to treat both solid and liquid foods. Treating food with ultrasonic waves inactivates the microorganisms present in it and thus serves to pasteurize the food. This method is applied at room temperatures, whereas normal pasteurization takes place at higher temperatures, which may not be suitable for all types of food.

Another application of ultrasonics in food technology is the analysis and assessment of any product. High-frequency ultrasonic waves from 100 kHz to 1 MHz at a power less than 1 W/cm² are used for this purpose. The acidity, ripeness, sugar content, and other physicochemical parameters of the product can be determined by this technology.

High-intensity ultrasonic waves using higher power in the range 10–1000 W/cm², but having a low frequency from about 16–100 kHz are used to make physical or chemical changes in the food, aiding in enhancing the quality

of the product. As an example, the food products such as meat or potatoes that are kept in cold storage tend to lose weight. Power ultrasound treatments affect the humidification systems in cold storage so that the weight loss decreases to a great extent. Similarly, the freeze-drying process can be replaced by ultrasonic drying, with no change in the colour, flavour, and nutritional value of the dried product. Fruits can be processed effectively by this process, in a shorter time interval than competing technologies. This not only speeds up the process but also enhances the nutritional value as the moisture content increases and the cooking time reduces when this method is applied to dry foods.

6. Ultrasonic cleaning

–these days many eyewear companies advertise that their glasses are ultra-cleaned, using ultrasonics. Not only glasses but this technology is also employed in many industries for cleaning a wide spectrum of materials ranging from fragile spectacles to heavy engine parts, from expensive jewelry to intricate electronic components, from medical equipment to military weapons. Ultrasonic cleaning instruments have been used since the 1950s. The process involves the use of a suitable liquid cleaner. The object to be cleaned is immersed in this liquid along with an ultrasound generator. When the signals of ultrasonic frequency are generated, they cause compression waves in the fluid, resulting in what is termed ‘cavitation.’ These are

microscopic vacuum bubbles, which, when collapsed, release a large amount of energy. This energy is sufficient only to dislodge the contaminants from the object, without damaging it in the least. It is to be noted that this process of ultrasonic cleaning does not sterilize the object. It only removes grime or other contaminants. Microorganisms like viruses are not eliminated by this process. Hence medical instruments cleaned by this process need to undergo a subsequent sterilization process before being utilized. Also, an effective drying process is necessary for electronic parts cleaned by this method to avoid short-circuiting as ultrasonic cleaning requires the components to be submerged in suitable liquids.

7. Mechanical Processing of Materials

–there are a variety of mechanical processes which can be accomplished by ultrasonic waves. Drilling holes or cutting metal sheets can be easily done using ultrasonic waves. Normal welding of metals requires a very high temperature. This can be done at room temperature using ultrasonic waves.

Some alloys, like lead-aluminum or lead-tin-zinc, are not easily formed using conventional metallurgical methods and are formed by ultrasonic processes. Shaking together two metals using ultrasonic waves causes them to mix and form into alloys.

Metals like aluminum cannot be soldered using the normal soldering iron. But when the electric soldering iron is used in conjunction with ultrasound, it facilitates the soldering of aluminum.

Conclusions

Ultrasonic waves are a clean substitute for many radioactive electromagnetic waves like X-rays and gamma rays. Their production methods are simpler, and the equipment is generally portable. Further research in the field will definitely yield more applications in diverse fields.

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सत्यमेव जयते

Government of India
Ministry of Earth Sciences

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Azadi Ka
Amrit Mahotsav



स्वच्छ सागर - सुरक्षित सागर
Clean Coast - Safe Sea

Swachh Sagar, Surakshit Sagar

5th July-17th Sept. 2022



India is proud to have a vast coastline of 7,500+ Kilometres. A longest and beautiful one. Isn't it?

However, litter especially in the form of plastics in the marine environment are a major concern and growing international problem and a number of studies have shown their harmful impact on marine biodiversity, ecosystems, fisheries, human health and economy.

The "International Coastal Cleanup Day" is celebrated globally on the third Saturday of September, every year. This year on 17th September 2022, the Government of India along with other voluntary organizations, and the local

society will run a cleanliness campaign "Swachh Sagar, Surakshit Sagar/ Clean Coast, Safe Sea" along India's entire coastline.

This campaign will be led by Ministry of Earth Sciences, and supported by a number of other Government & Non-Government agencies like, Ministry of Environment Forest and Climate Change, National Service Scheme, Indian Coast Guard, National Disaster Management Authority, Seema Jagran Manch, SFD, Paryavaran Sanrakshan Gatividhi, Indian Institute of Public Administration, Ministry of Education, Ministry of Shipping, Ports

& Waterways, Ministry of Jal Shakti, NCC, Ministry of Fisheries, Ministry of Science & Technology, Department of Space & Atomic Energy among others.

This year's event also coincides with the celebrations of Azadi Ka Amrit Mahotsav on 75th year of the India's independence; The coastal cleanup drive will be carried out on 75 beaches across the country with 75 volunteers for every kilometre of the coastline.

The campaign started on July 5th, 2022 and has three strategic underlying goals, which are to 1. Consume Responsibly; 2. Segregate Waste at Home, and 3. Dispose Responsibly. The



7500+
Kilometres
Coastline

75
Days of
Activities

Daman

1. Devka Beach
2. Jampore Beach

Maharashtra

3. Juhu Beach
4. Girgaon Chowpaty
5. Mandavi Beach
6. Malgunda Beach
7. Murud
8. Chikhale

Goa

9. Miramar
10. Baina
11. Bogmalo
12. Velsao
13. Colva Beach

Karnataka

14. Panambur Beach
15. Malpe Beach
16. Gortee Beach
17. Aghanashini Beach

Kerala

18. Beypore Beach
19. Cherai Beach
20. Kuzhipally Beach
21. Azheekal Beach
22. Kovalam Beach

Lakshadweep

23. Katchery Jetty Beach
24. Moola Beach
25. Kodi Beach

Gujarat

26. Chowpati Beach
27. Madhavpur Beach
28. Somnath Beach
29. Ghoghla Beach

75
Popular
Beaches

30. Jhanjmer Beach
31. Pingleshwar Beach
32. Narara Beach
33. Mandavi Beach
34. Okha light house to Pawan Chakki
35. Dandi Beach

Andhra Pradesh

36. RK Beach
37. Yarada Beach
38. Rushikonda Beach
39. Kakinada Beach
40. NTR Beach
41. Dhindi Beach
42. Suryalanka Beach
43. Krishnapatnam Beach

Tamilnadu

44. Marina Beach
45. Besant Nagar Beach
46. Thiruvanmiyur Beach
47. Aryaman Beach
48. Pirappanvalasai Beach
49. VOC Beach
50. Muthunagar Beach
51. Mullakadu Beach

Puducherry

52. Gandhi Beach
53. Auroville Beach
54. Kilinjamedu Beach
55. Karaikal Beach

West Bengal

56. Haldai River Front Beach
57. Bakkhali Sea Beach
58. Henry Island Beach
59. Digha Beach

Odisha

60. Paradip Beach
61. Chandipur Beach
62. Chandravaga Beach
63. Puri Beach
64. Gopalpur Beach
65. Bateswar Beach

Andaman & Nicobar Islands

66. Kalipur Beach
67. Karmathatang Beach
68. Raman Bagicha Beach
69. Carbyn Coves Beach
70. Radhanagar Beach
71. Chattan Beach
72. Kanaka Beach
73. Gandhi Nagar Beach
74. Malacca Beach
75. Kalasi Beach

AWARENESS ACTIVITIES

For Students

- Competitions
- Exhibitions
- Nature Pledge on Teacher's Day
- SME Lecture Series
- Coastal Cleanup Drives

Coastal Communities

- Monsoon Beach Festival
- Sagar Shaniwar
- Film Shows

- Street Plays
- Coastal Cleanup Drives

Nationwide

- Mass Pledge for Coastal Cleanup
- Freedom from Plastic
- Cycle to Beach
- Team Up to Clean Up
- Celebrity Endorsements
- Coastal Cleanup Drives

Registration through EcoMitram App

campaign will culminate with the largest beach cleaning event on 17th September, covering 75 beaches across India's 7,500+ Km coastline.

A mobile app "Eco Mitram" has been launched to spread awareness about the campaign and also for the common people for voluntary registration for the beach cleaning activity.